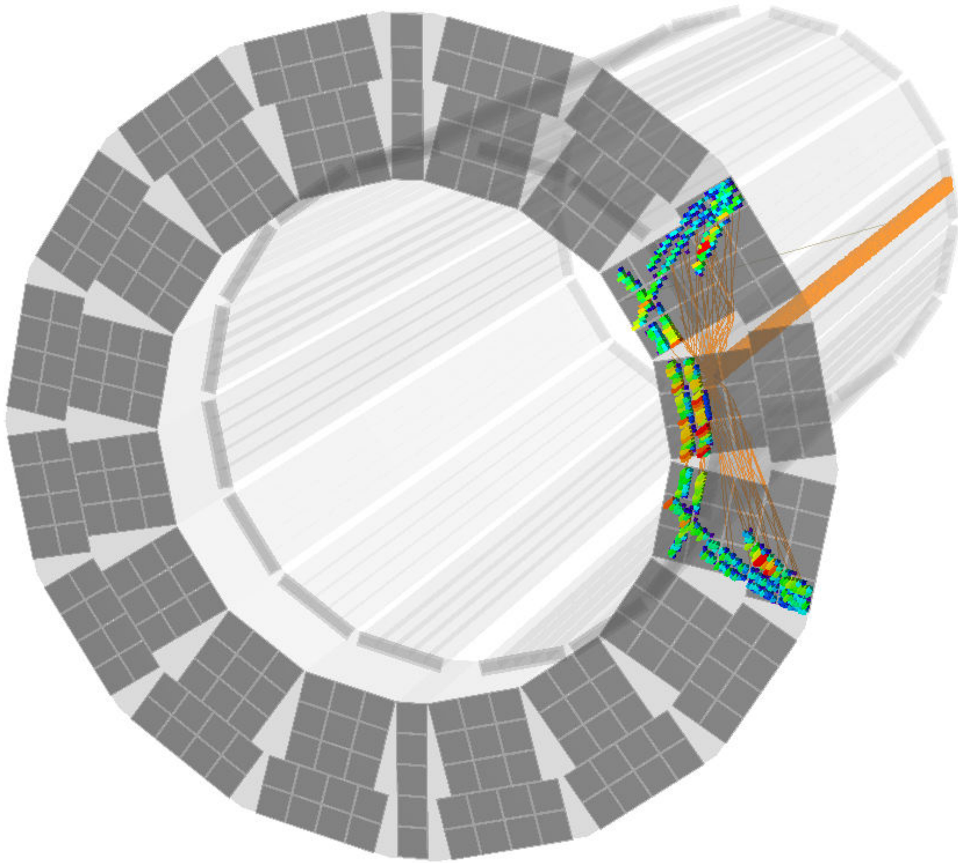
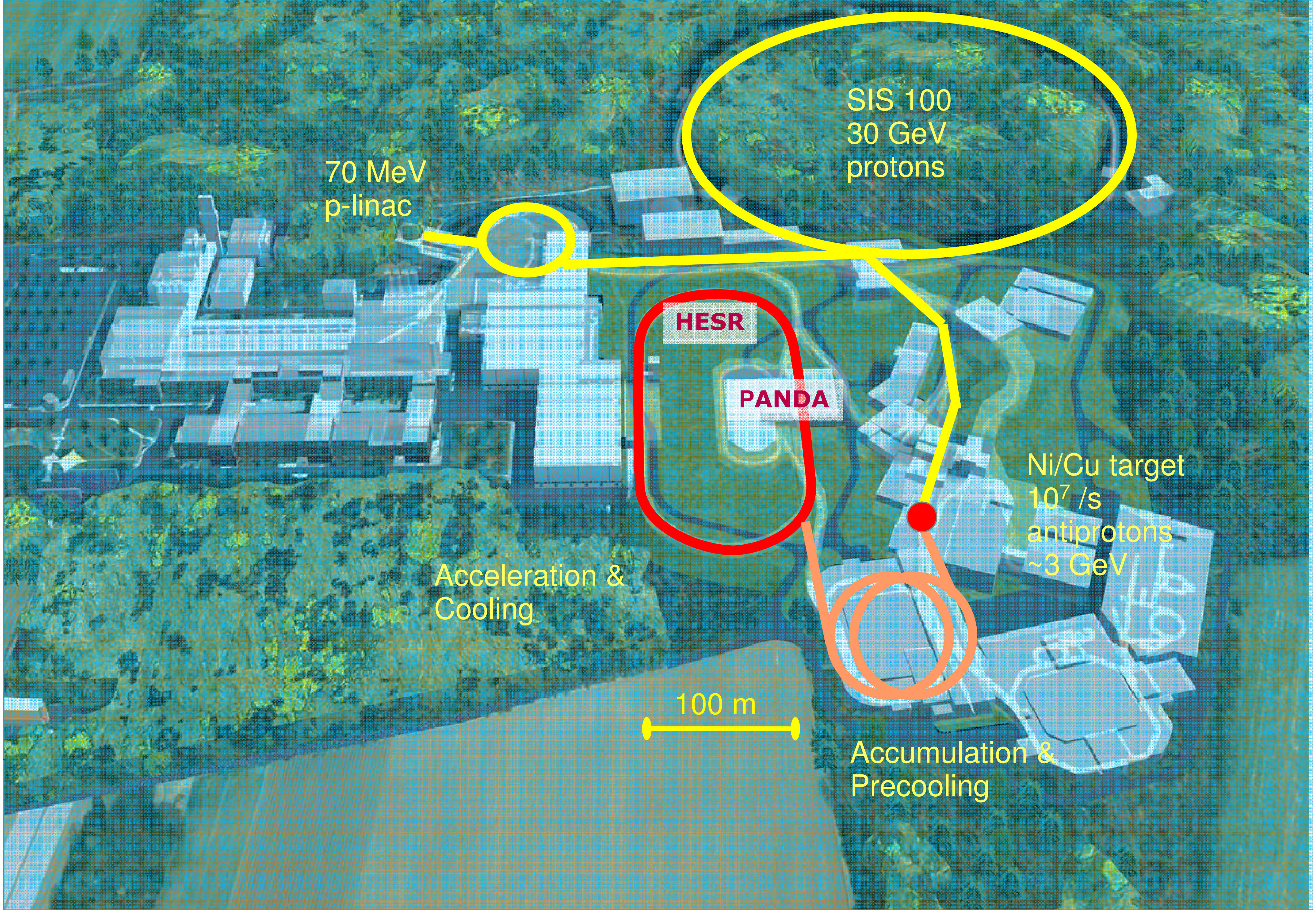
The PANDA Barrel DIRC

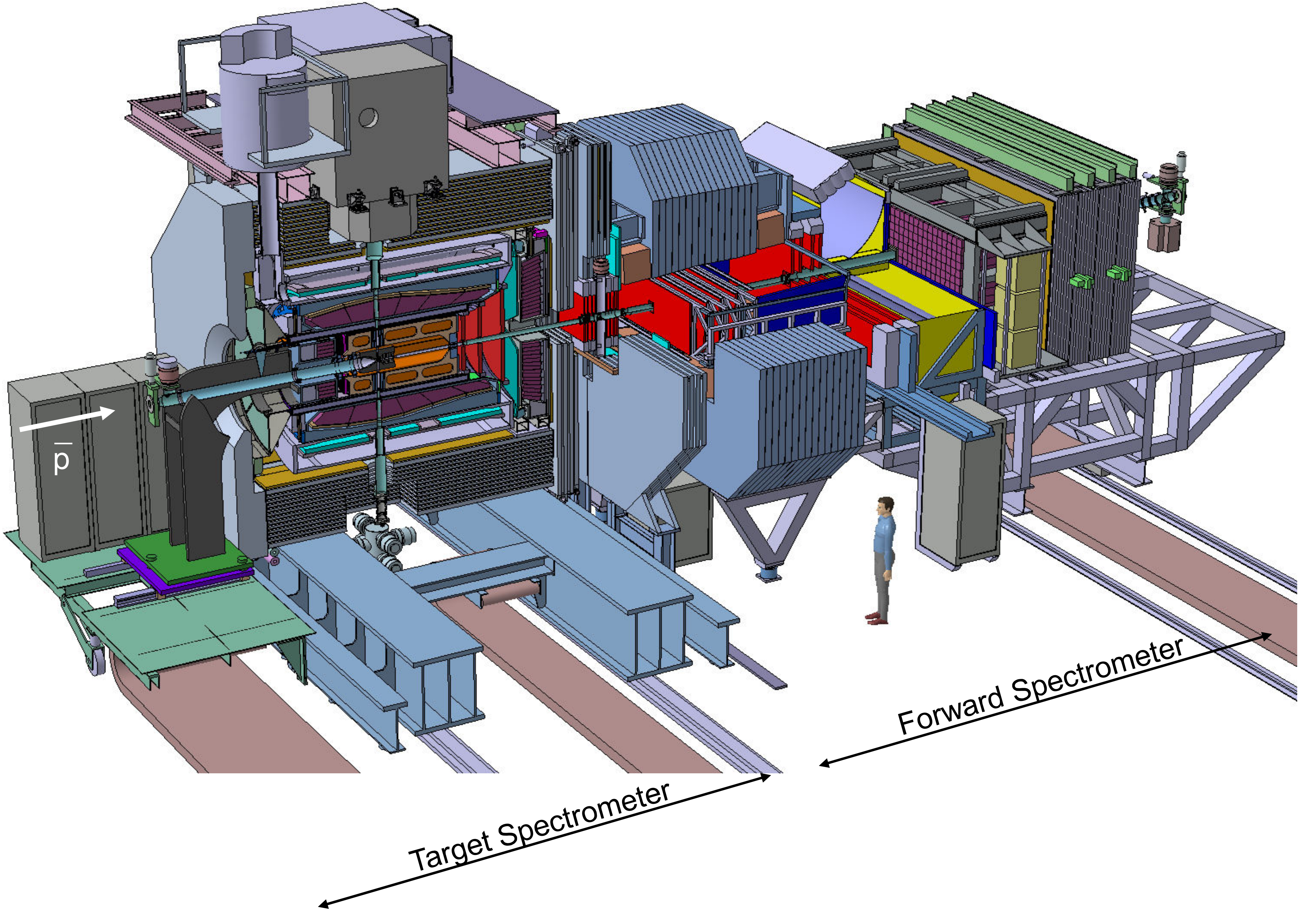
Carsten Schwarz, GSI, for the PANDA Cherenkov group

- FAIR and PANDA
- Baseline design
- Design options
- Test experiments

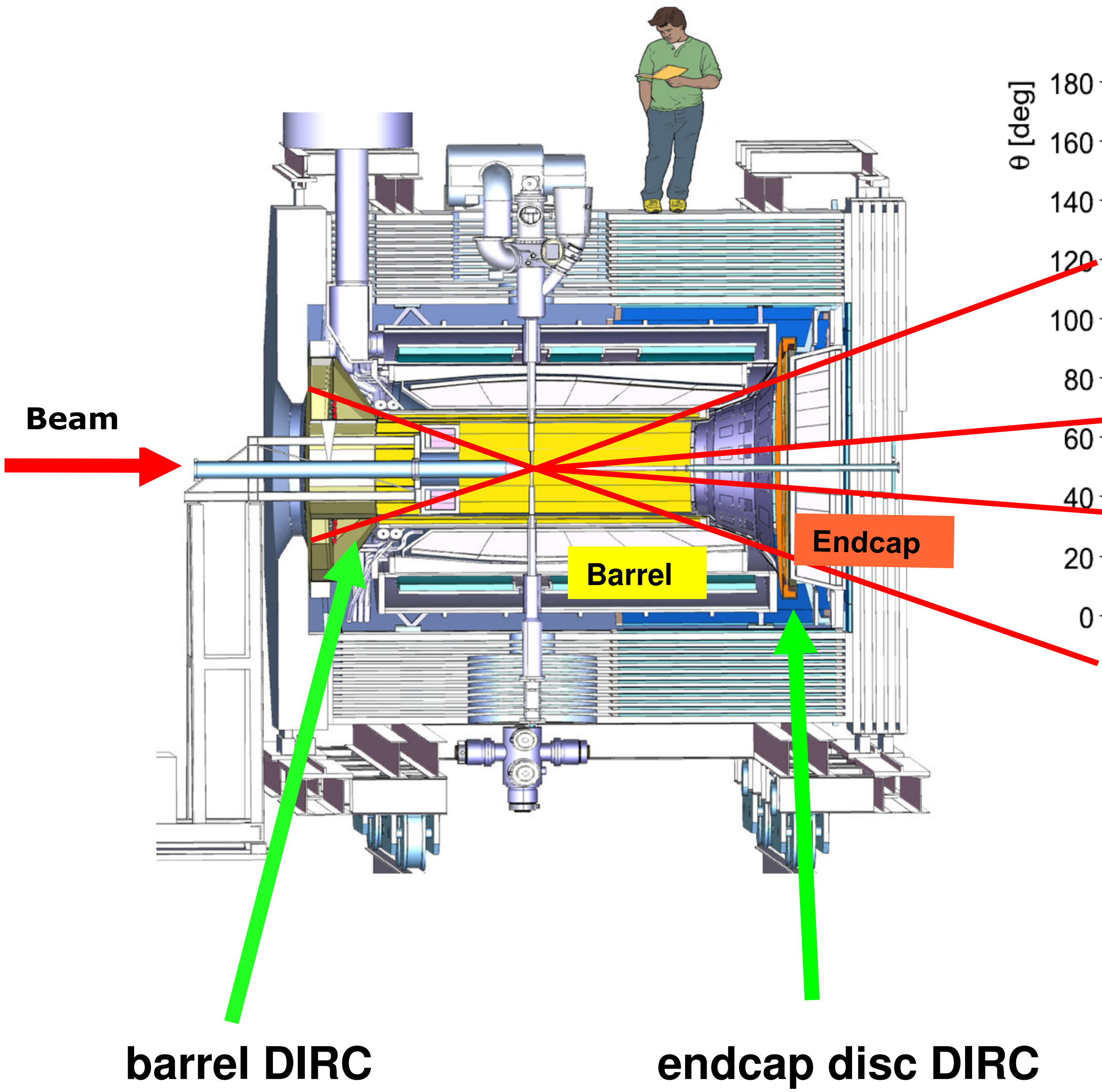


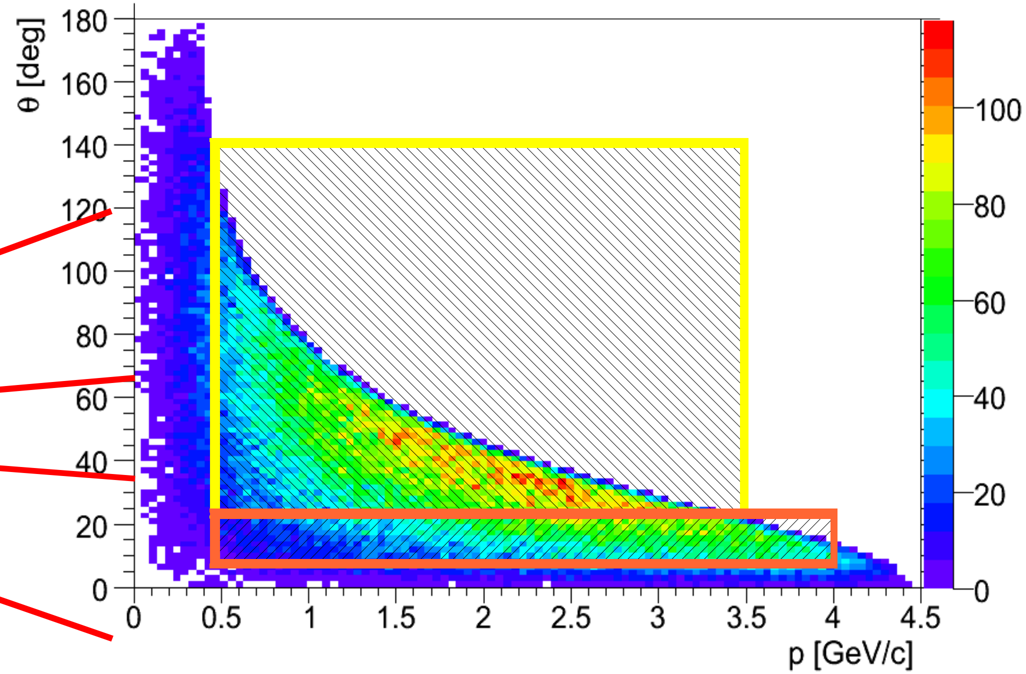
PANDA at FAIR




p̄
Target Spectrometer
Forward Spectrometer

PANDA DIRC counters

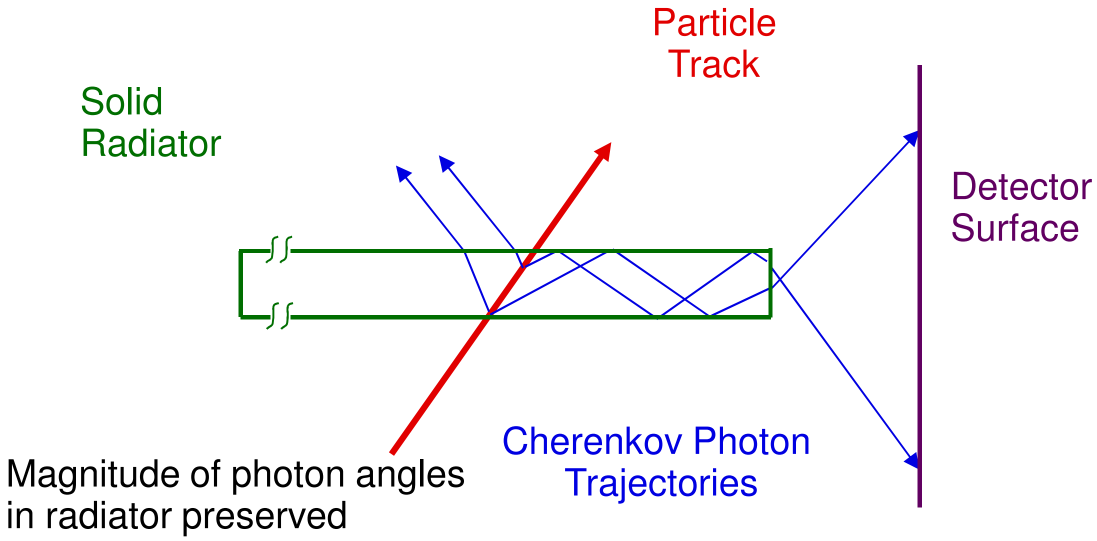




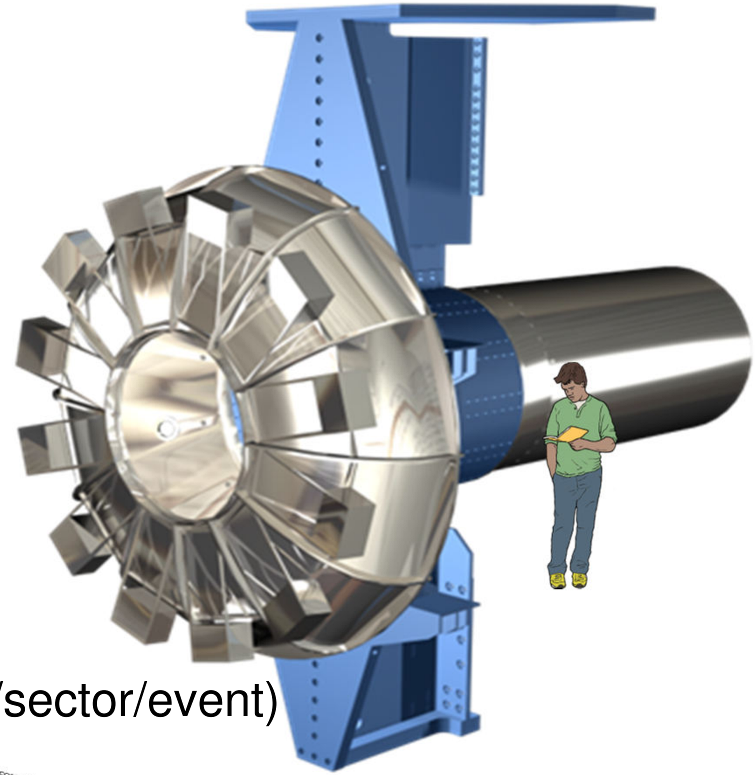
Kaon distribution of the radiative decay
J/ψ -> $K^+K^-\gamma$ (search for glue balls)

Barrel DIRC

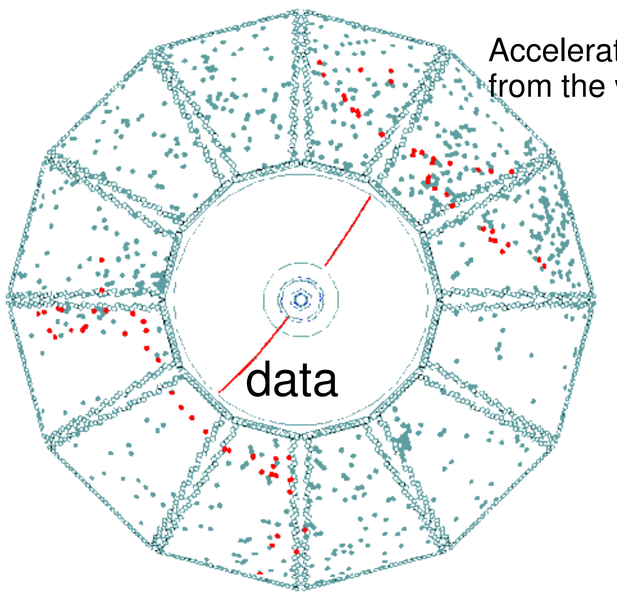
Detection of **I**nternally **R**eflected **C**herenkov light



BaBar DIRC , SLAC

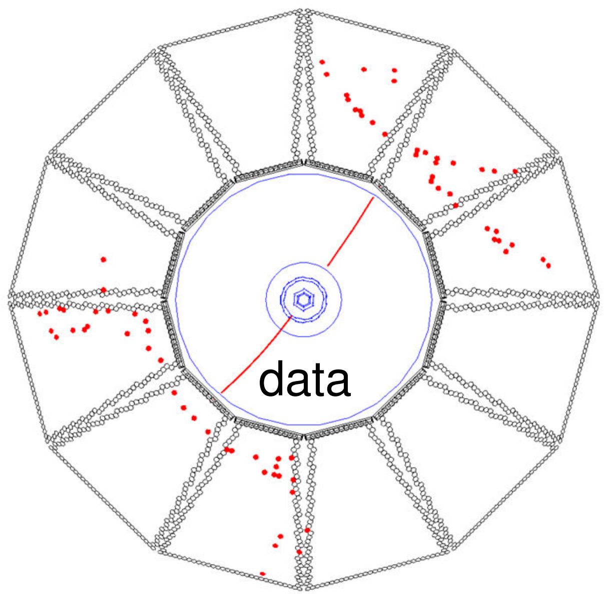


± 300 nsec trigger window (~500-1300 background hits/event) → ± 8 nsec Δt window (1-2 background hits/sector/event)



Accelerator background from the water tank

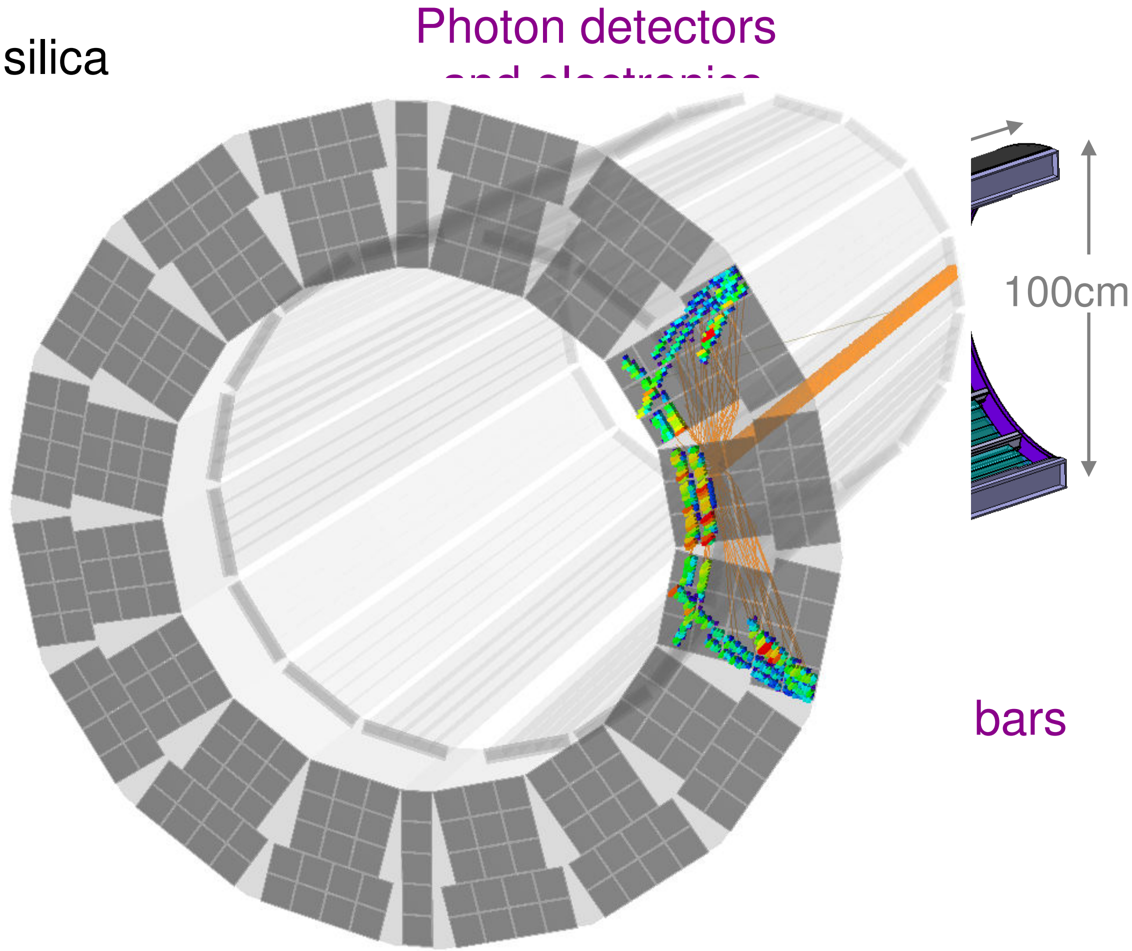
→



Baseline design: based on BABAR DIRC with key improvements

- Barrel radius ~48 cm; expansion volume depth: 30 cm.
- 80 narrow radiator bars, synthetic fused silica

  17mm (T) x 32mm (W) x 2400mm (L).



- Focusing optics: lens system.
- Compact photon detector:

  30 cm oil-filled expansion volume

  18000 channels of MCP-PMTs

  in ~1T B field.
- Fast photon detection:

  fast TDC plus TOT electronics,

  → 100-200 ps timing.
- Expected performance:

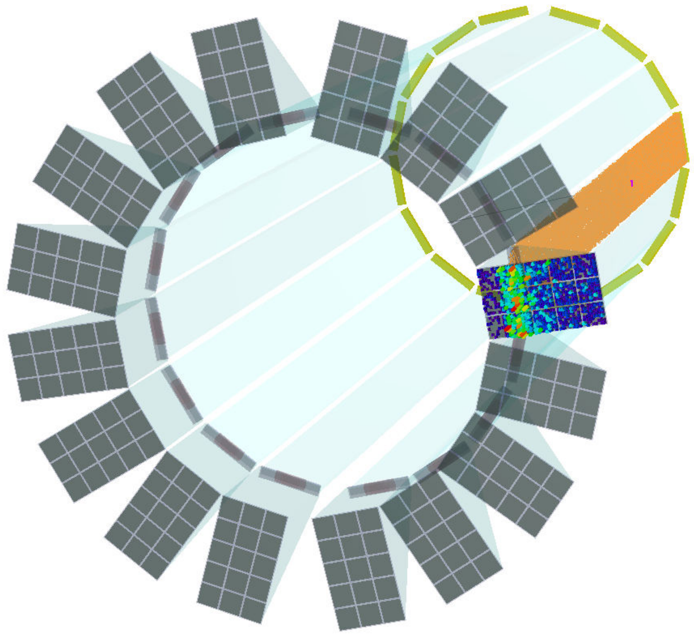
  Single photon Cherenkov angle resolution: 8-10 mrad.

  Number of detected photons for β≈1 track: at least 15.
- Design options:

  Radiator plates, prism, focusing options.

Investigating several design options:

Use of one wide fused silica plate (160 mm) per sector
instead of 5 narrow (32 mm) bars.



Belle II iTOP is leading the way with plate fabrication, prototyping, and software development.

Smaller number of pieces would drastically reduce the radiator fabrication cost (1.5M€+ savings possible).

Segmented optical expansion volume: "camera" (like FDIRC, iTOP)

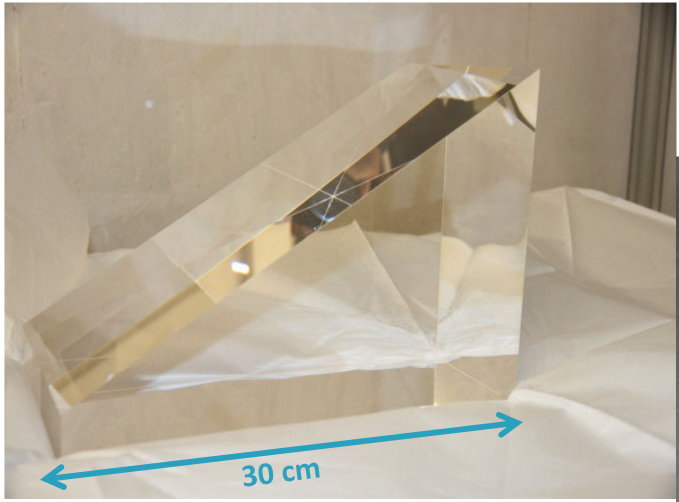
one solid fused silica prism per sector instead of oil tank.

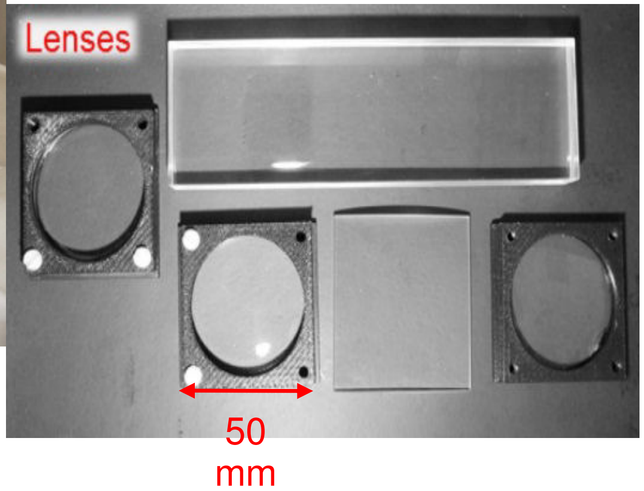
→ better optical and operational properties, good match to wide plates.

But: reflections in prism complicate reconstruction for narrow bars, add background.

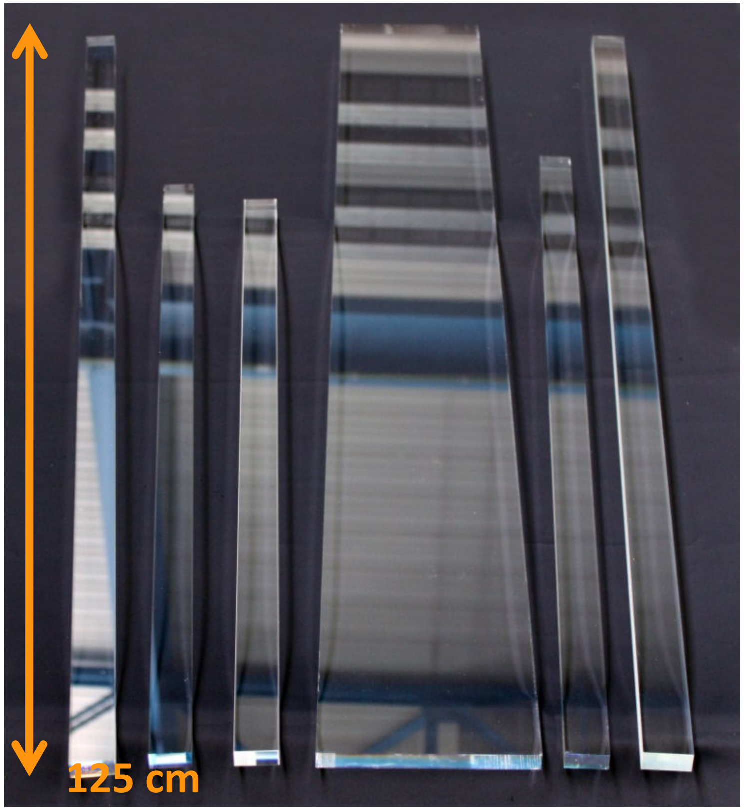
Design also reduces the number of required MCP-PMTs.

Ongoing prototyping of optical elements





Optical elements:

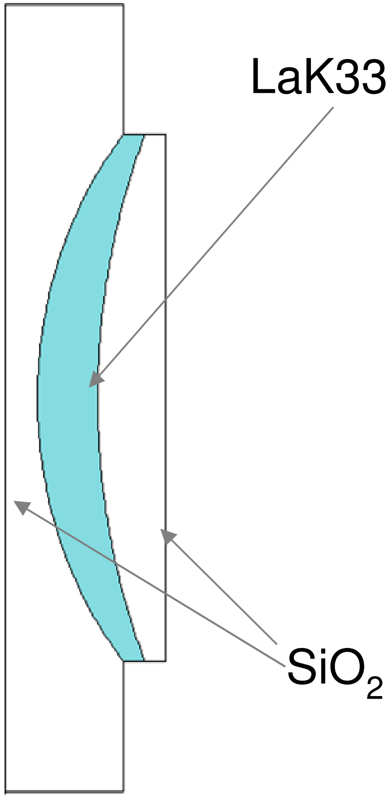


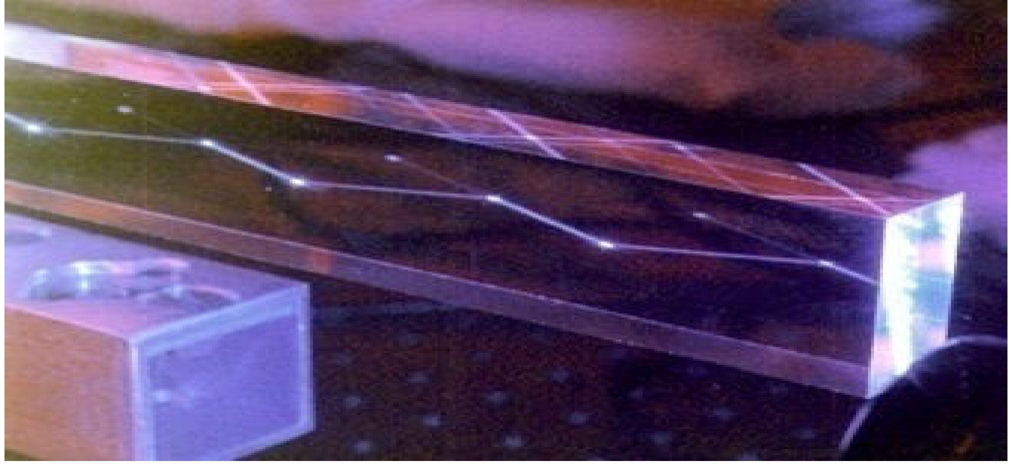
Radiators produced with different technologies and materials

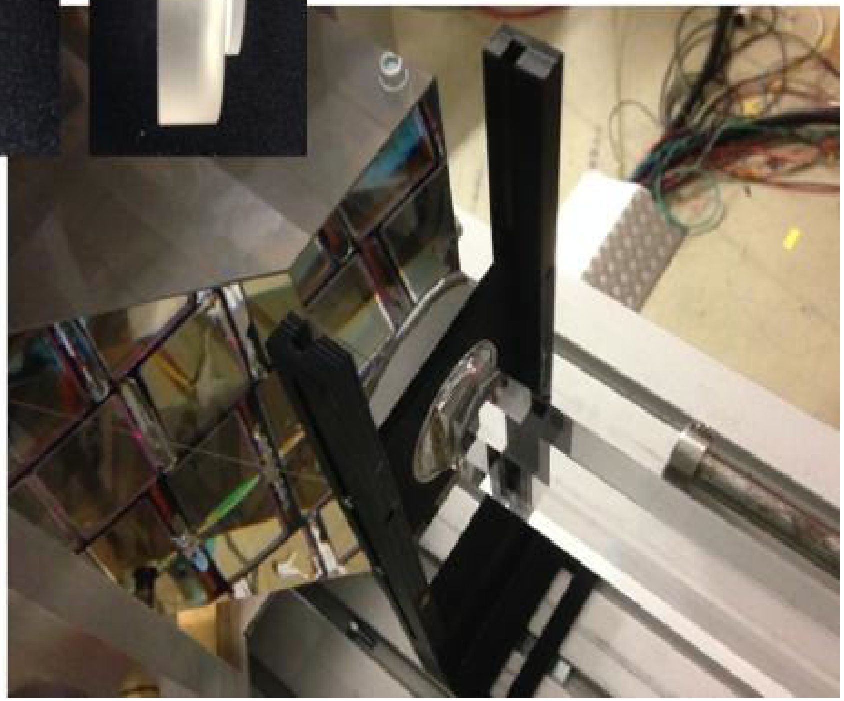
Quality assurance in optical laboratory at GSI and by producer

… soon a plate from Nikon

Lens design aimed for a focal plane matching the flat photon detector plane







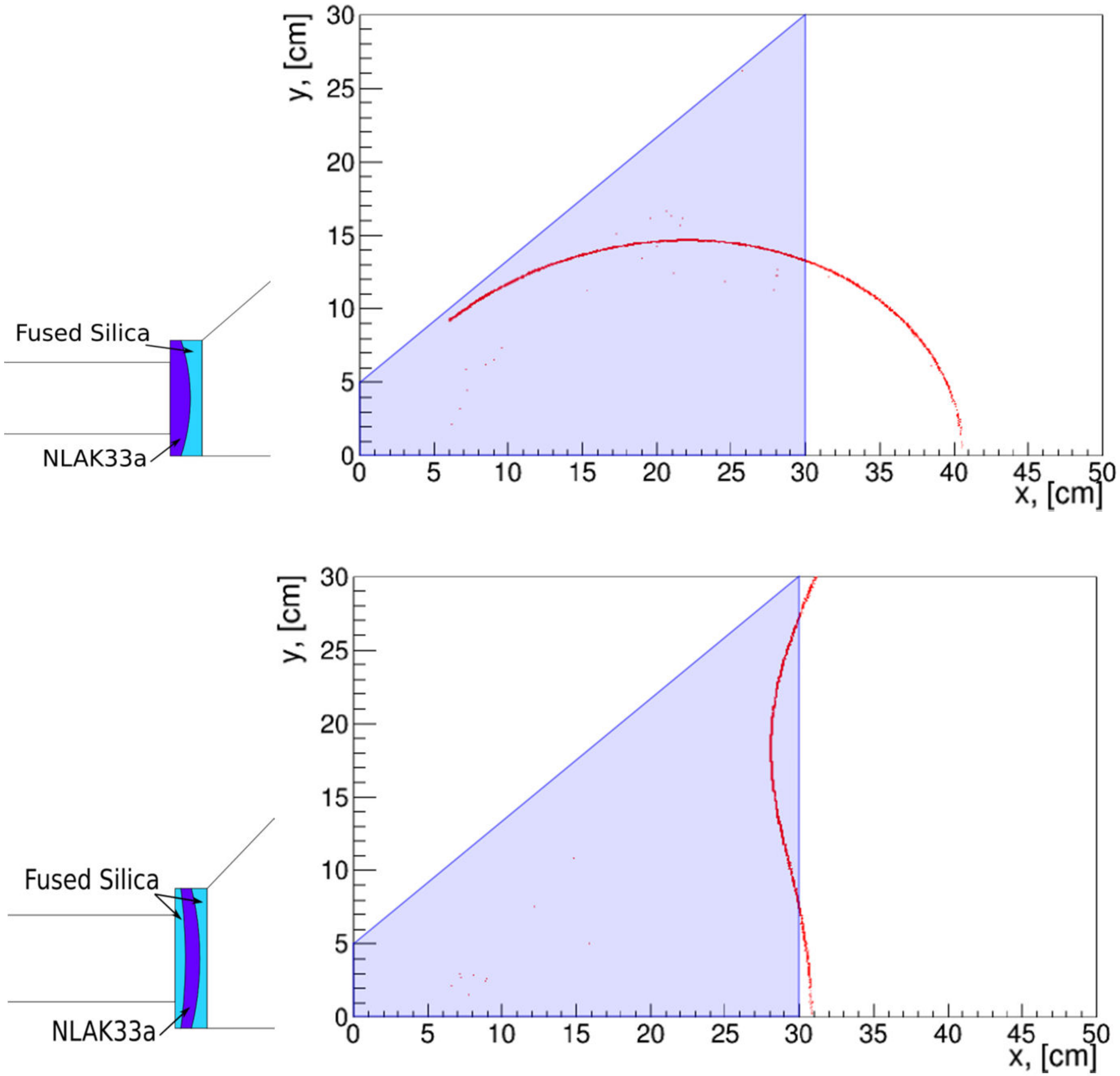
Radiation level ~ 10 kR

PbF_2 is radiation hard, γ ~ 100 kR
Other optical radiation resistant glasses?

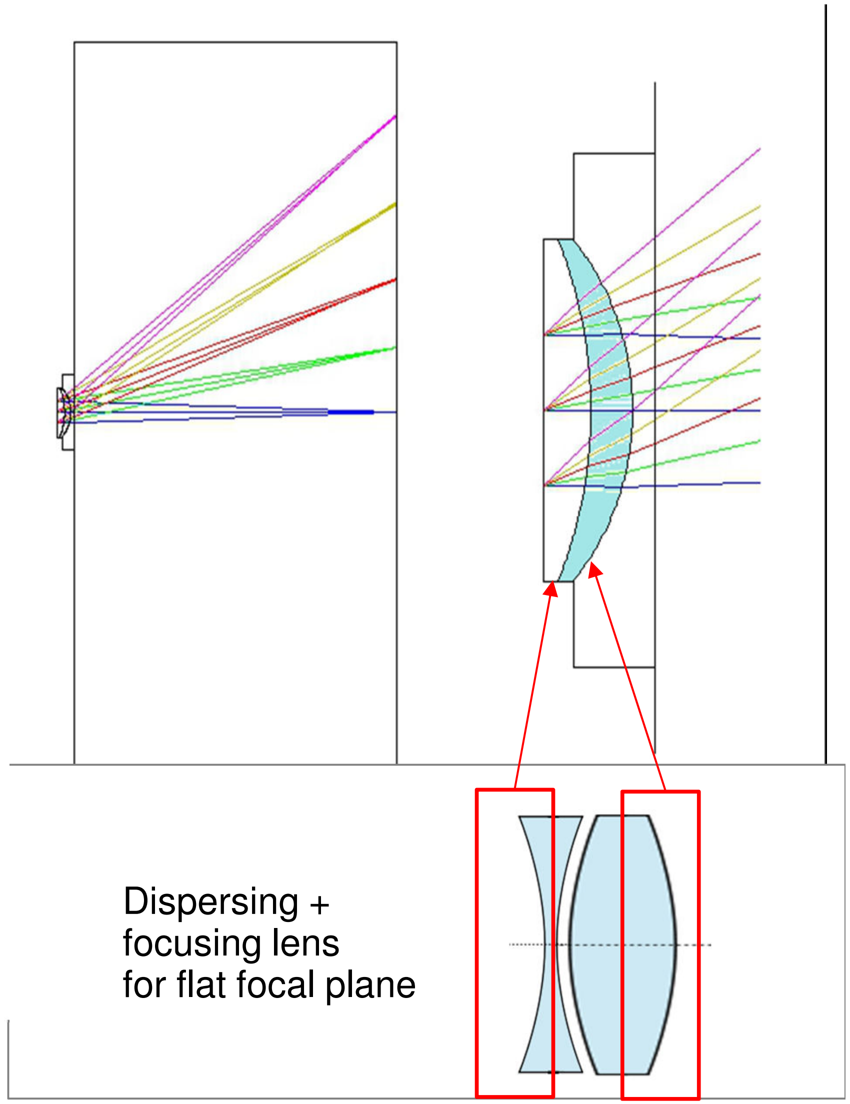
Afternoon, Lee Allison

Optical software: Spherical lens

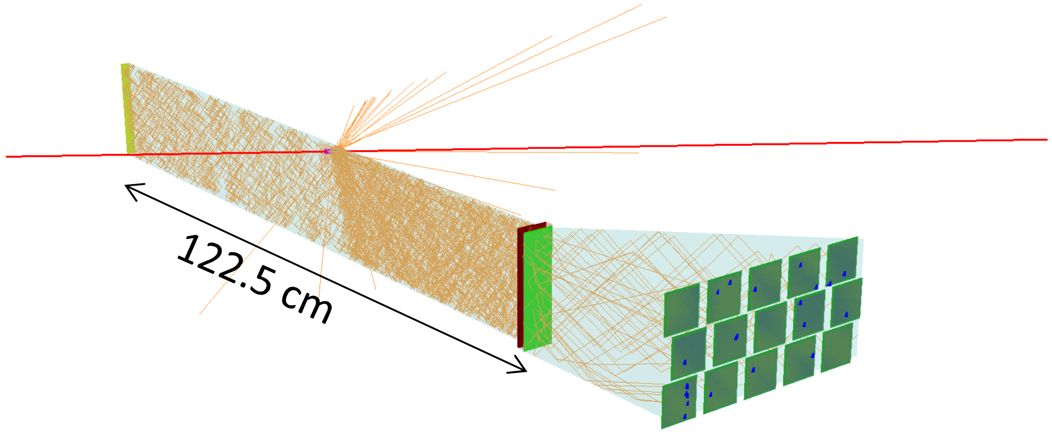
Geant



Zemax



Photon detector



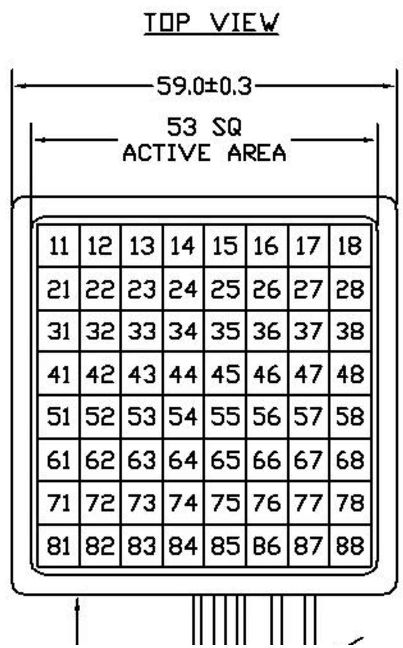
5 x 3 Planacon MCP-PMT (XP85012/A1-Q, Photonis)
960 pixels (in total >1200 readout channels)

with **pixel size 6.5 x 6.5 mm^2**

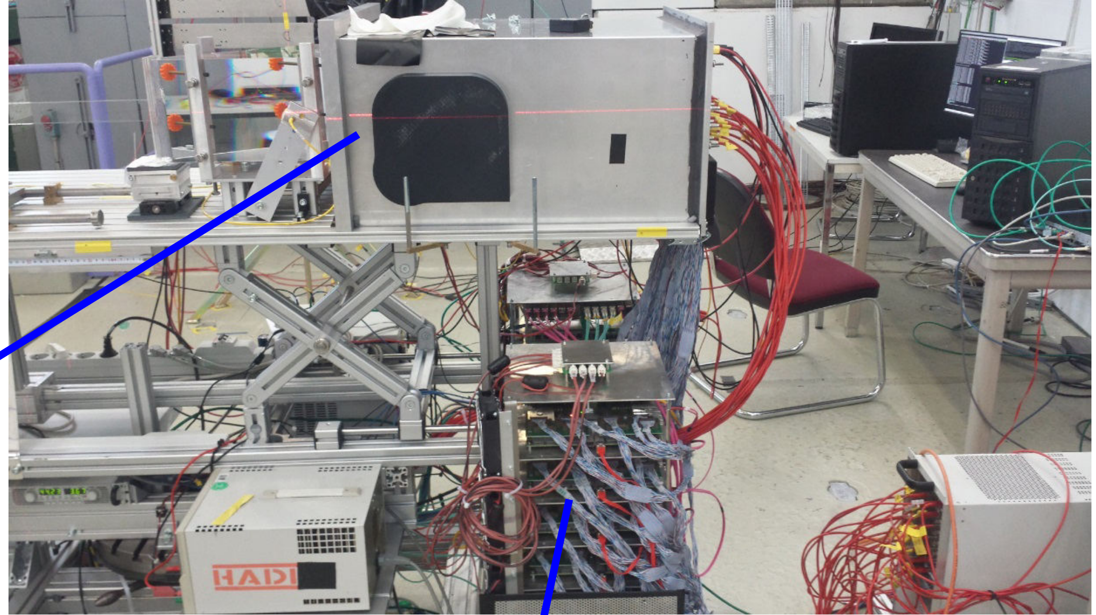
Work in **1T magnetic field**

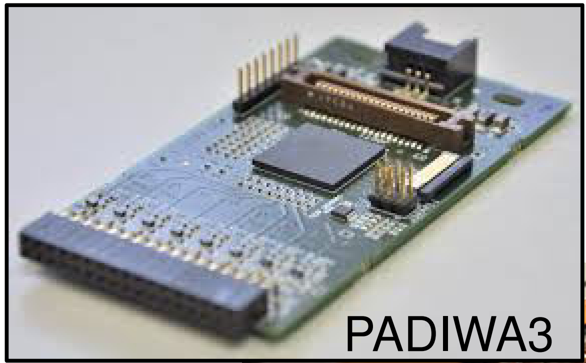
Survive **10 years** of PANDA (ageing)

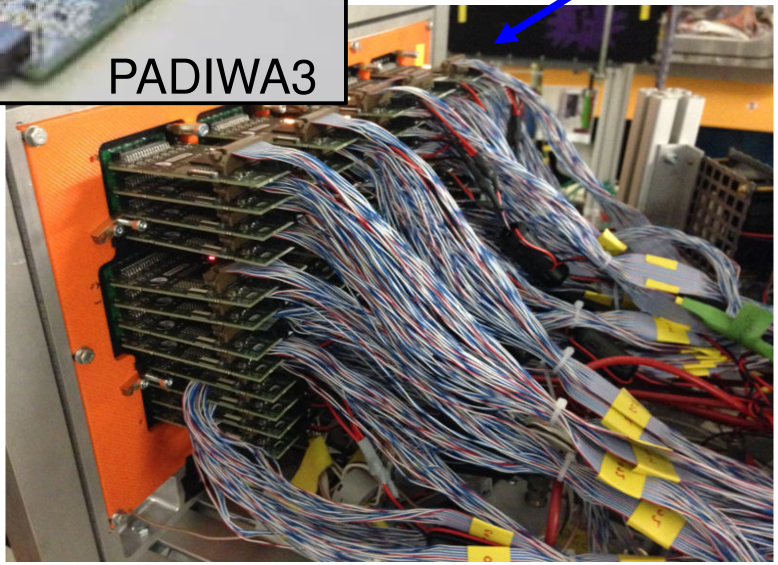
Wednesday, Albert Lehmann

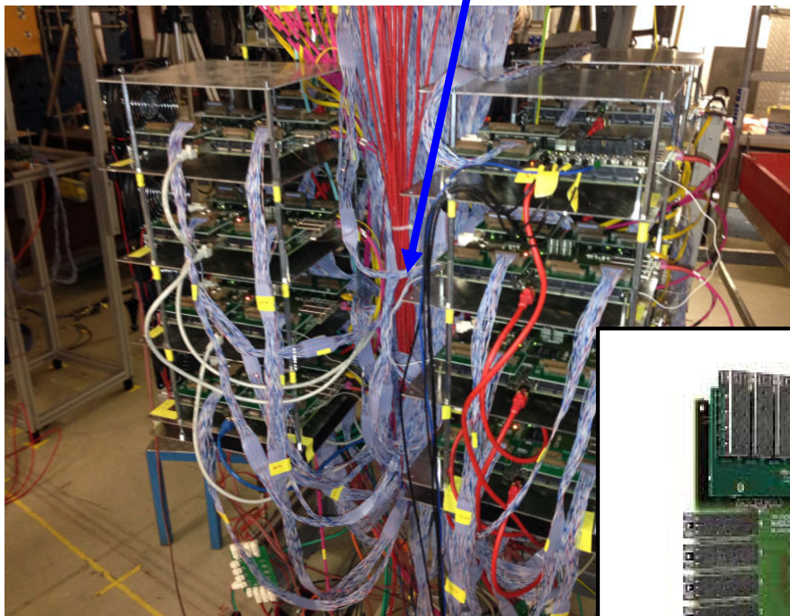


Readout chain









PADIWA3 discriminator

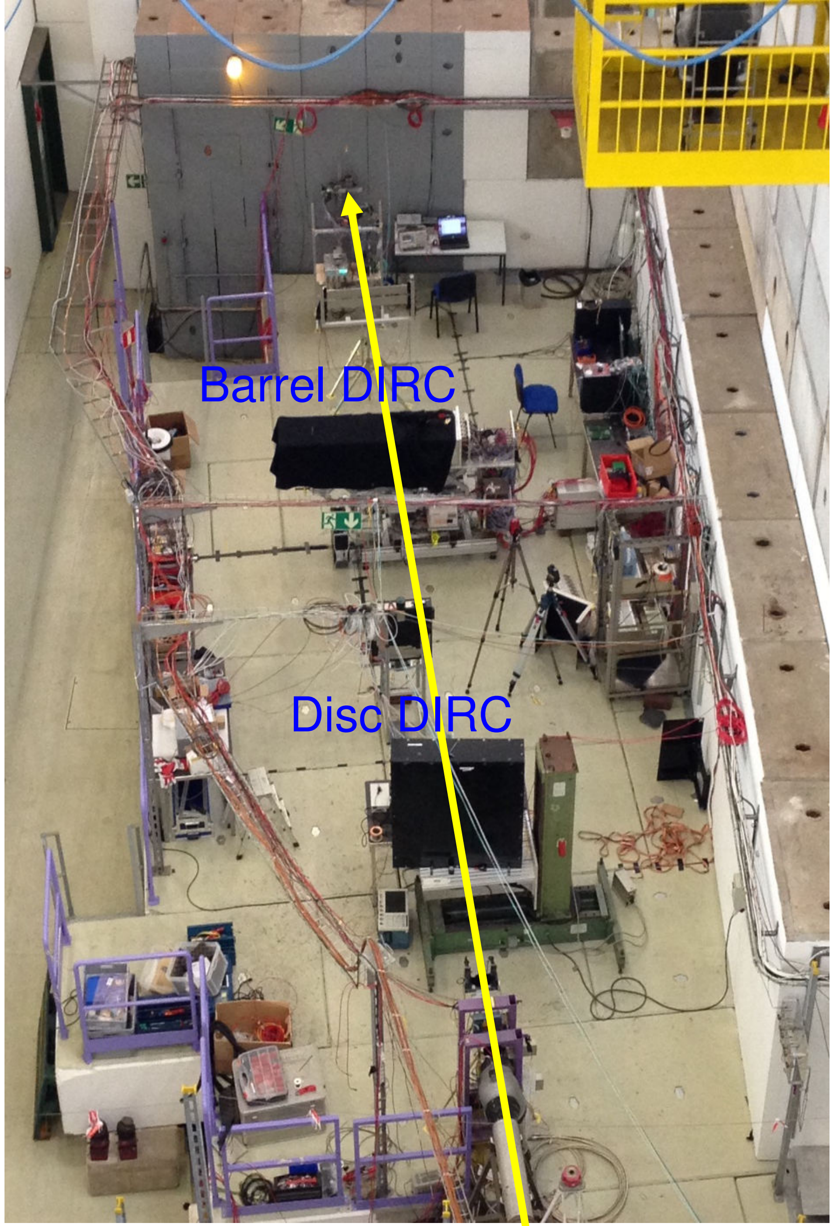
- Keep It Small & Simple = KISS
- Amplifier + LVDS discriminator

TRB3 TDC board

- Leading edge → timing (~10ps)
- Trailing edge → TOT → walk correction

Friday morning, Michael Traxler

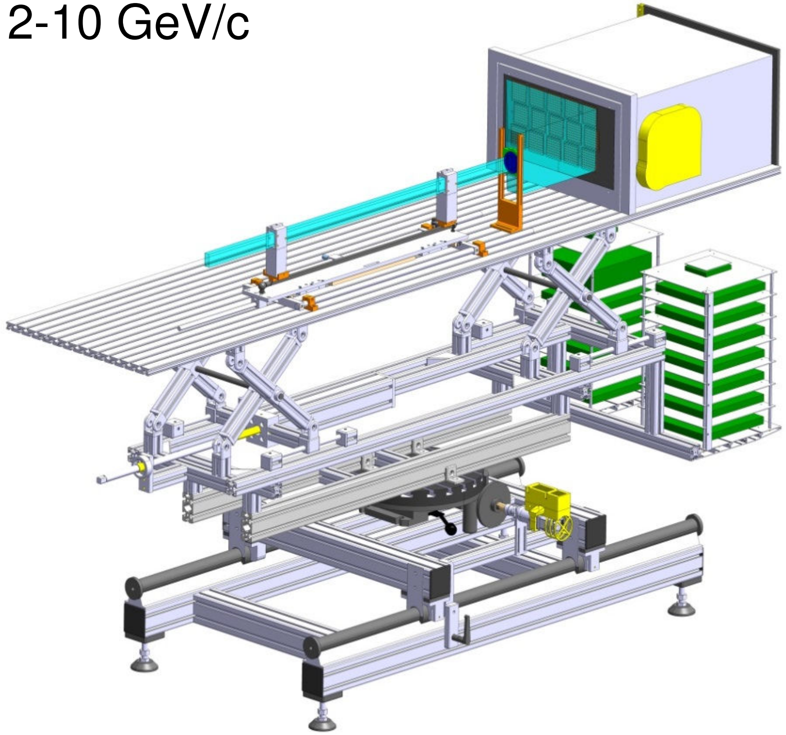
Experiments, CERN 2015, T9



29 m TOF

Joint effort of groups from
GSI, Uni Mainz, Uni Giessen, Uni Erlangen, JLab, and Old Dominion University.

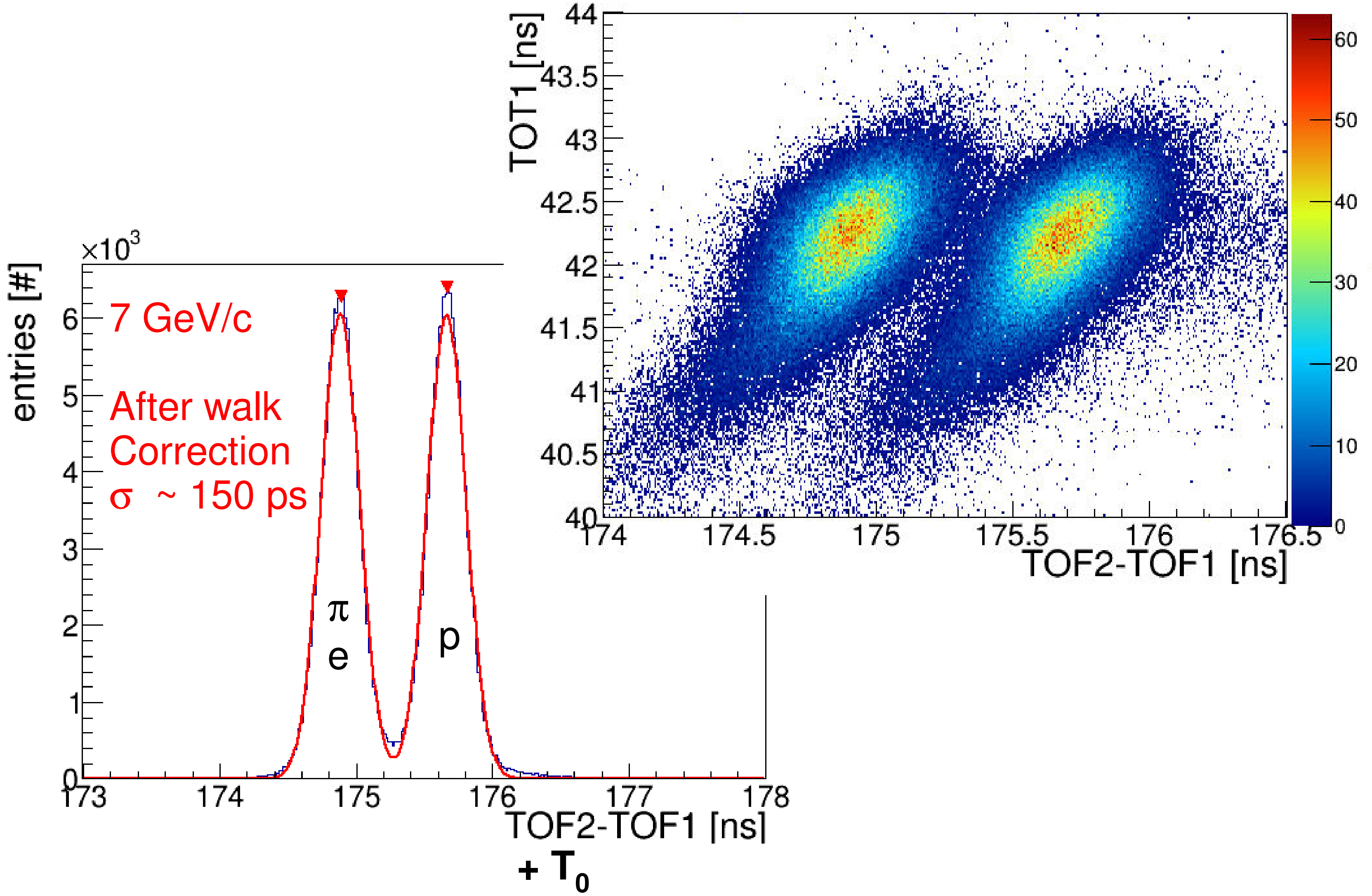
Hadron beam with mainly pions and protons with momenta 2-10 GeV/c



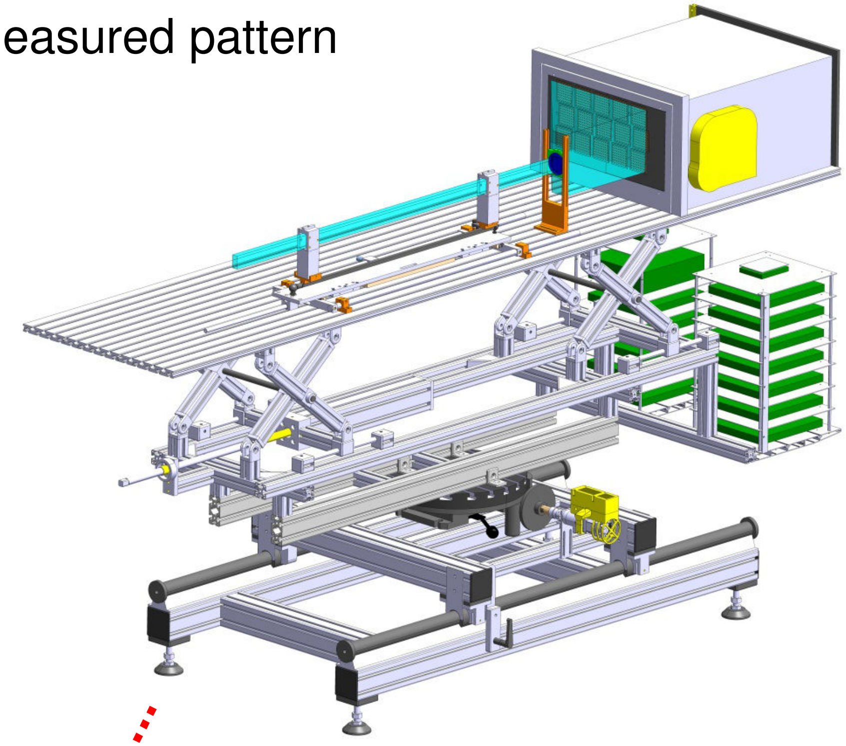
Measured:

- Several bars/plates of different vendors
- High-n cylindrical/spherical lenses
- Wide range of beam-bar angles and positions

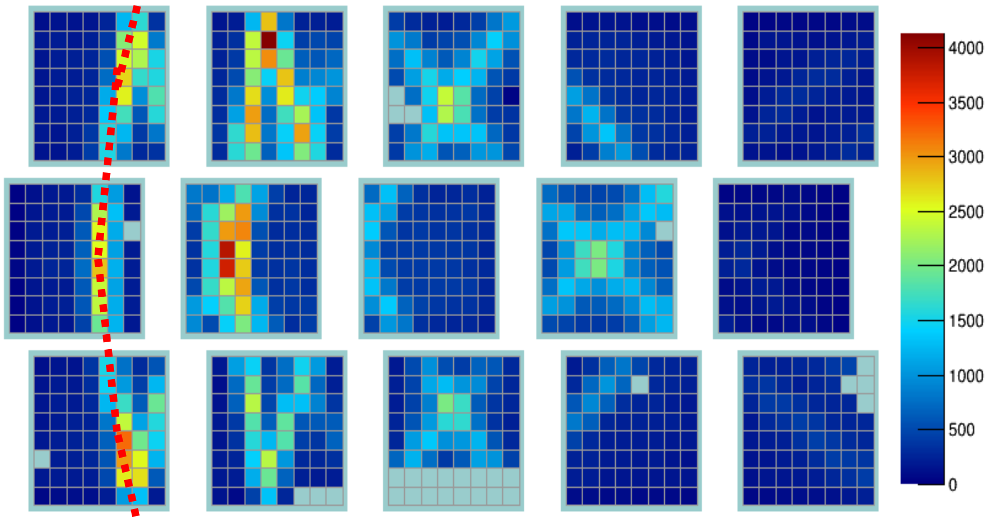
TOF counters allow to separate pions from protons up to 10 GeV/c



Measured pattern



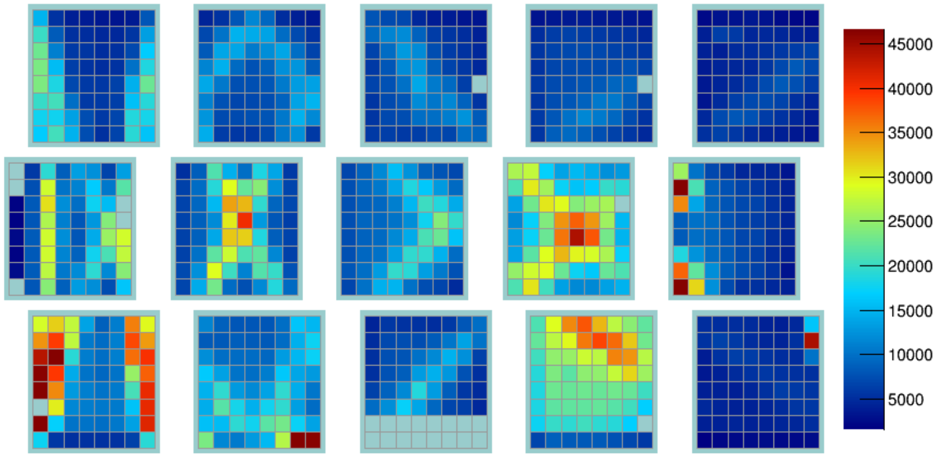
view from back



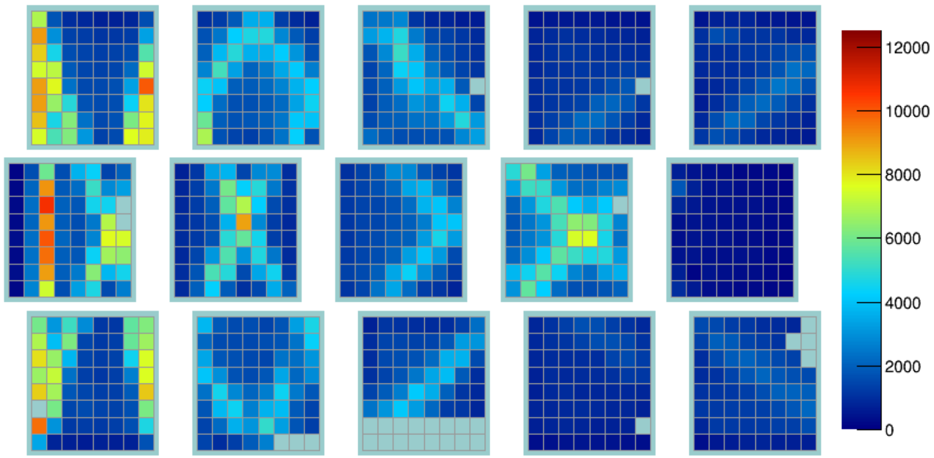
p, 3 GeV/c

Observed Cherenkov rings are folded

hit pattern for 3-layer lens, 7 GeV/c, 50 degree



Before hit & event selection



After hit & event selection

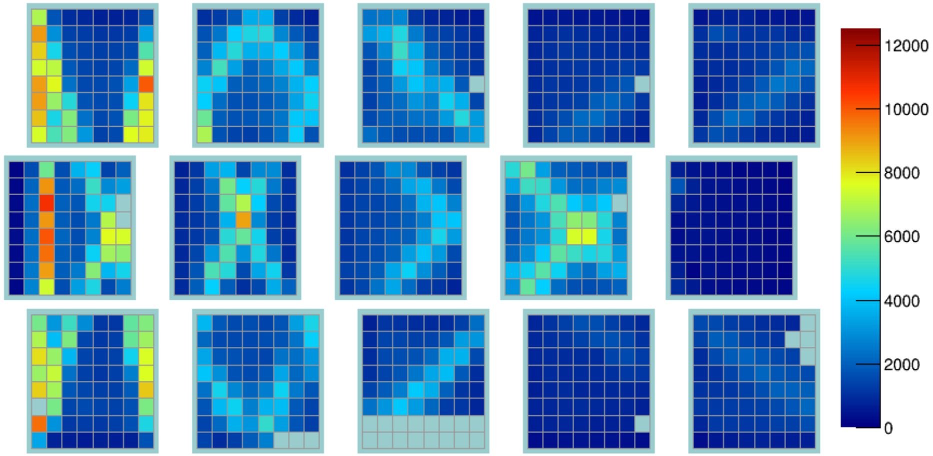
Event: Time cut around triggertime (scintillator in the beam)

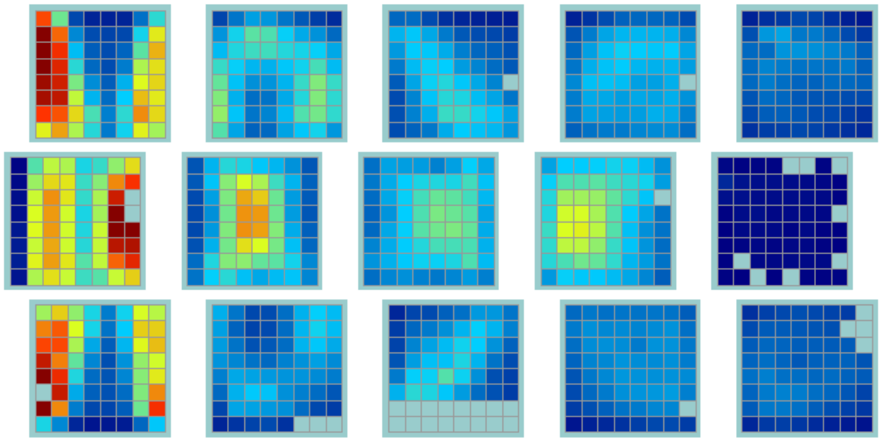
Hit: Masking noisy pixel
For each channel timing cuts
- Time offset calib. with laser data

→ Noise reduction

Don't forget the lens...

hit pattern for 3-layer lens
7 GeV/c, 50 degree

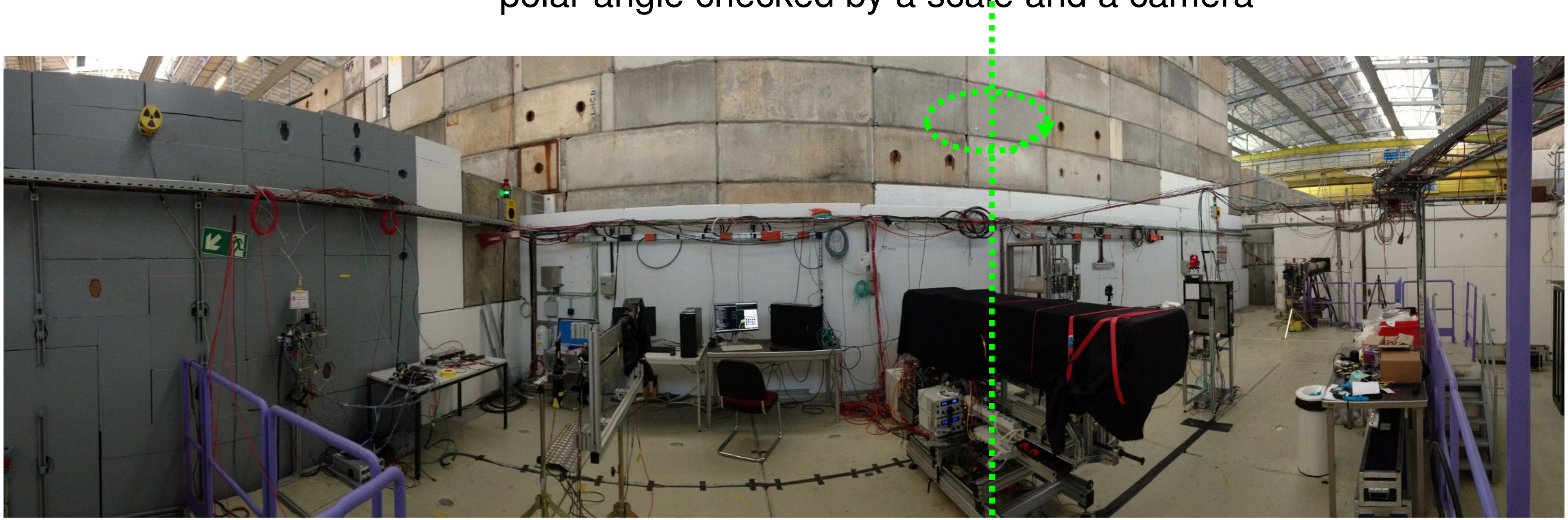




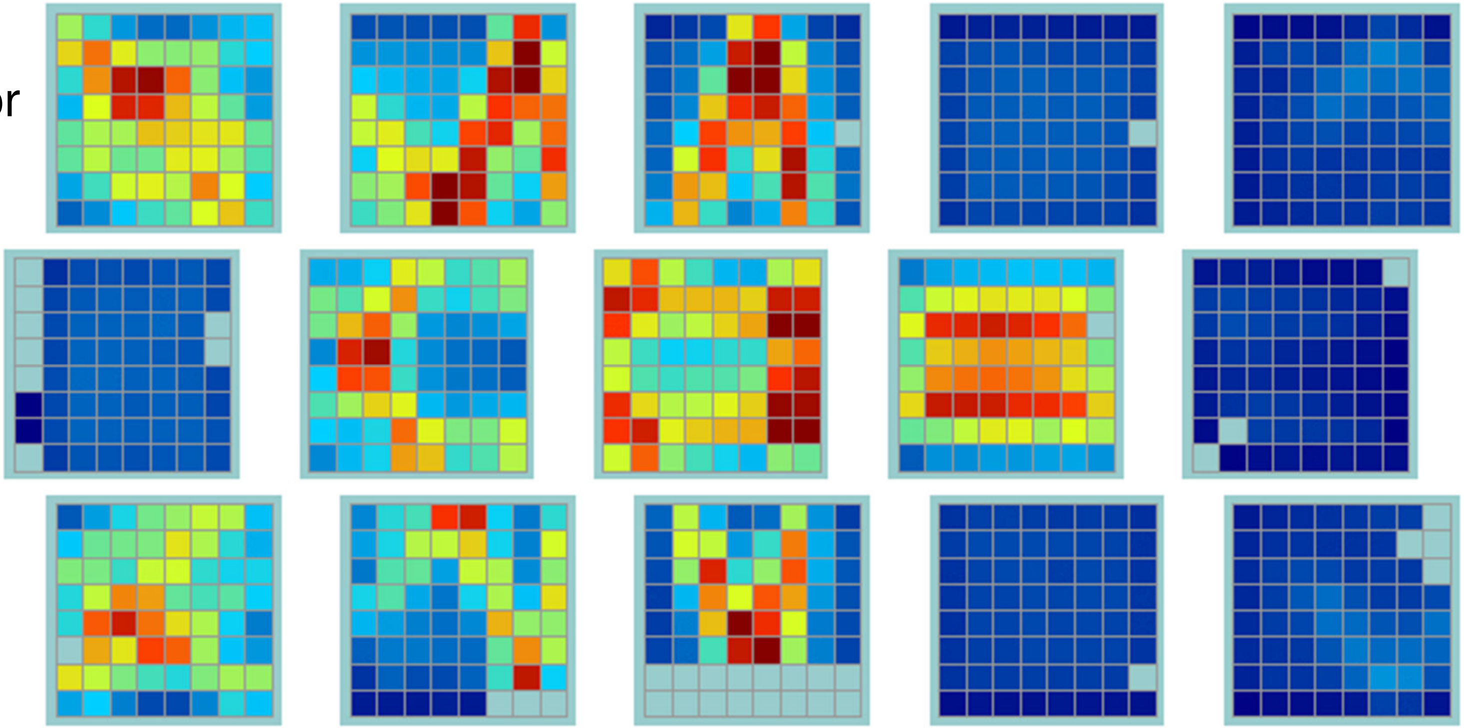
no lens

Angular scans

Setup was rotated remotely by a motor,
polar angle checked by a scale and a camera

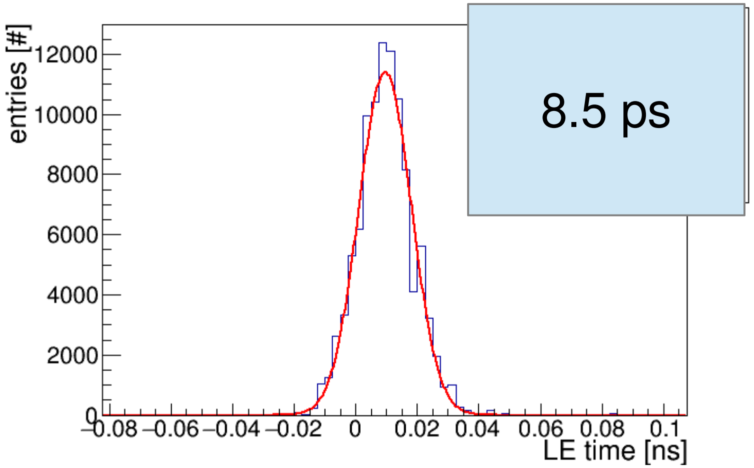


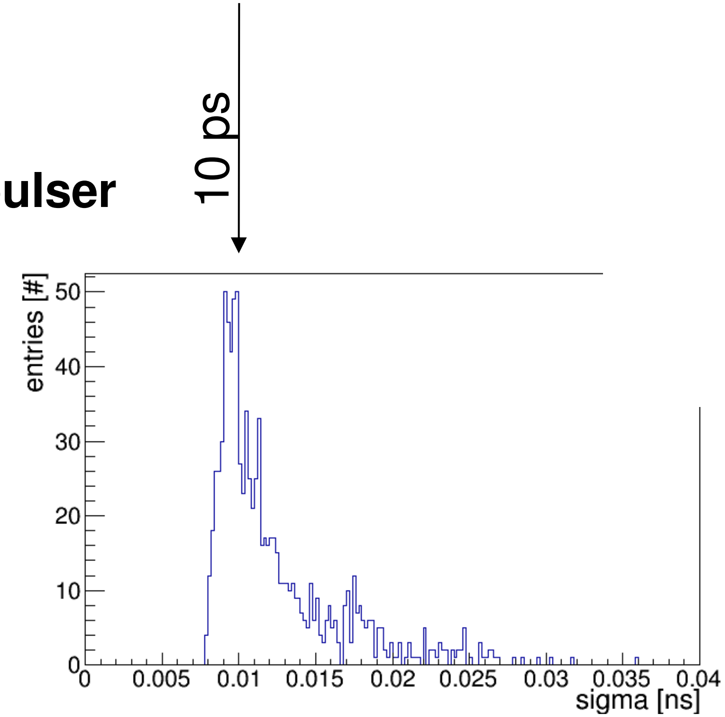
Movie of many angular measurements for bar with 3-layer lens @ 7 GeV/c



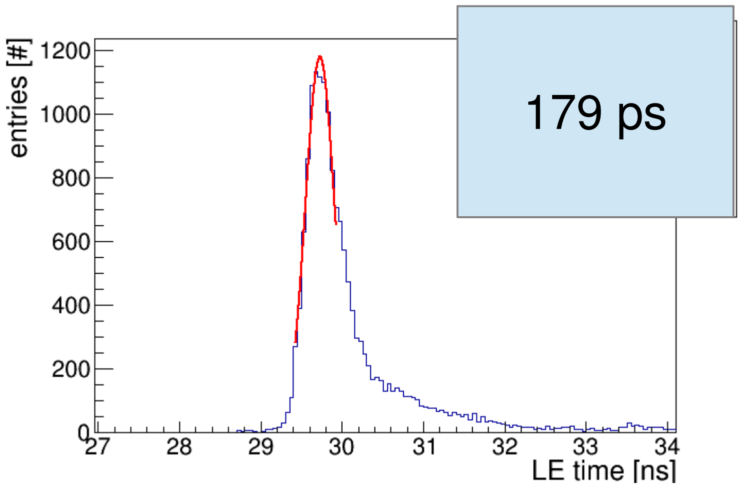
Time resolution

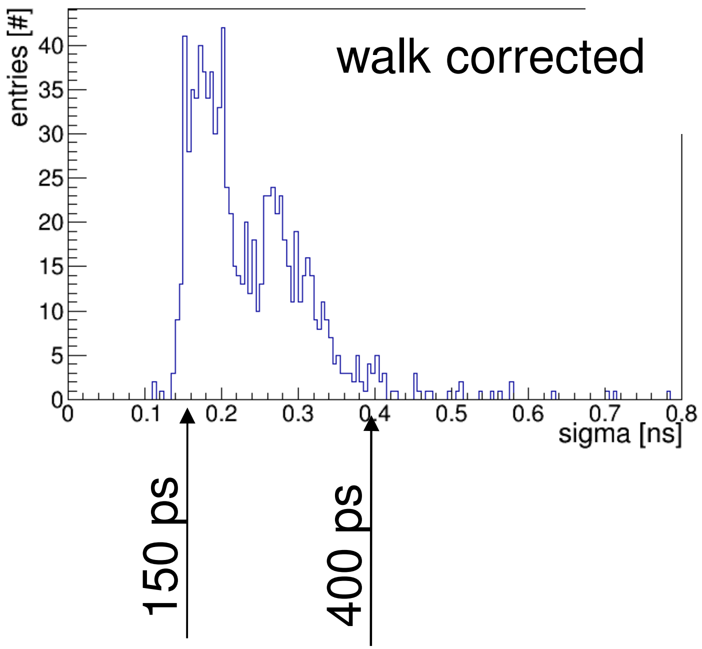
TRB: TDC channels with **internal pulser**





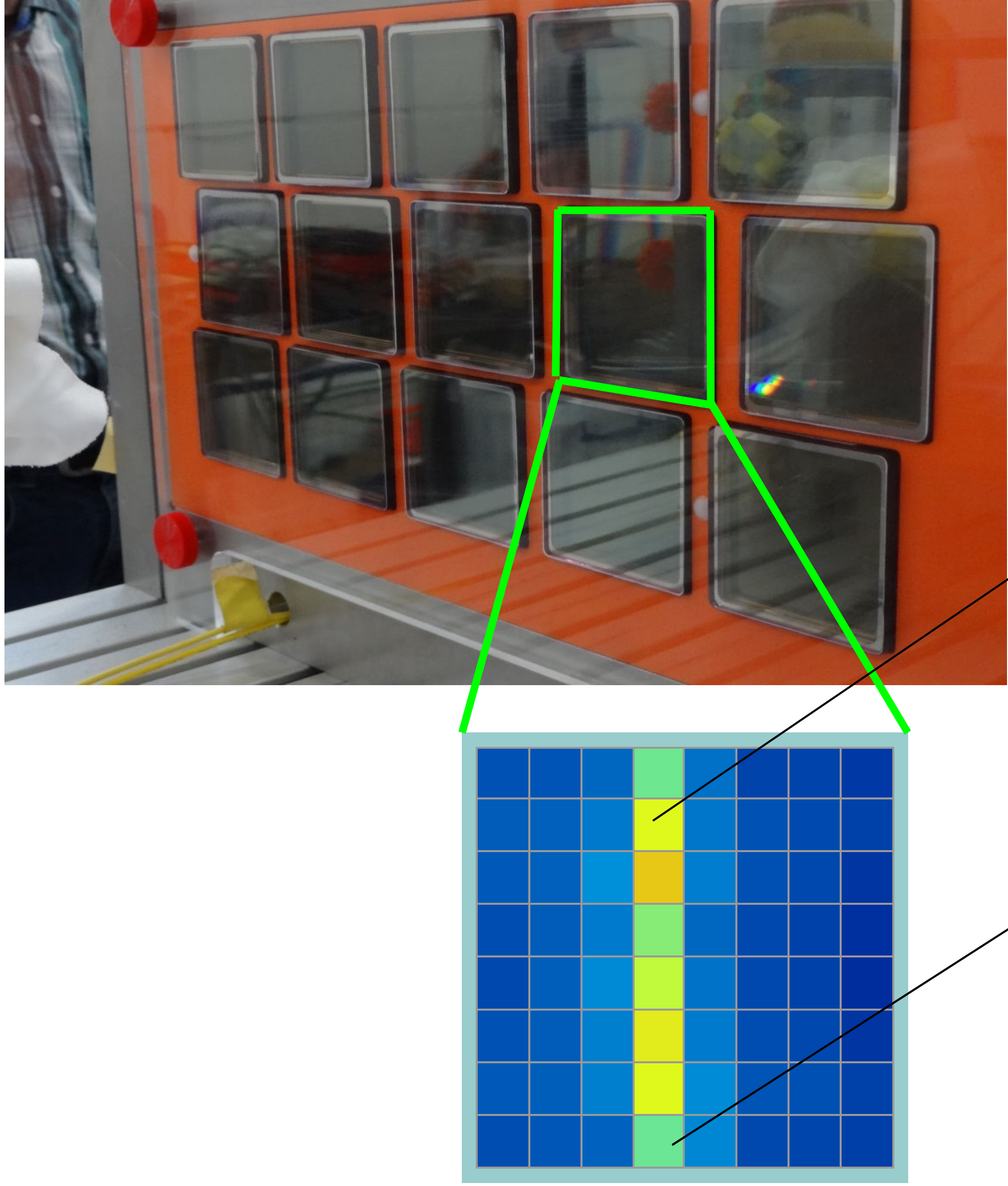
Chain: PMT-PADIWA -TRB with **Picoquant-laser** (80ps)

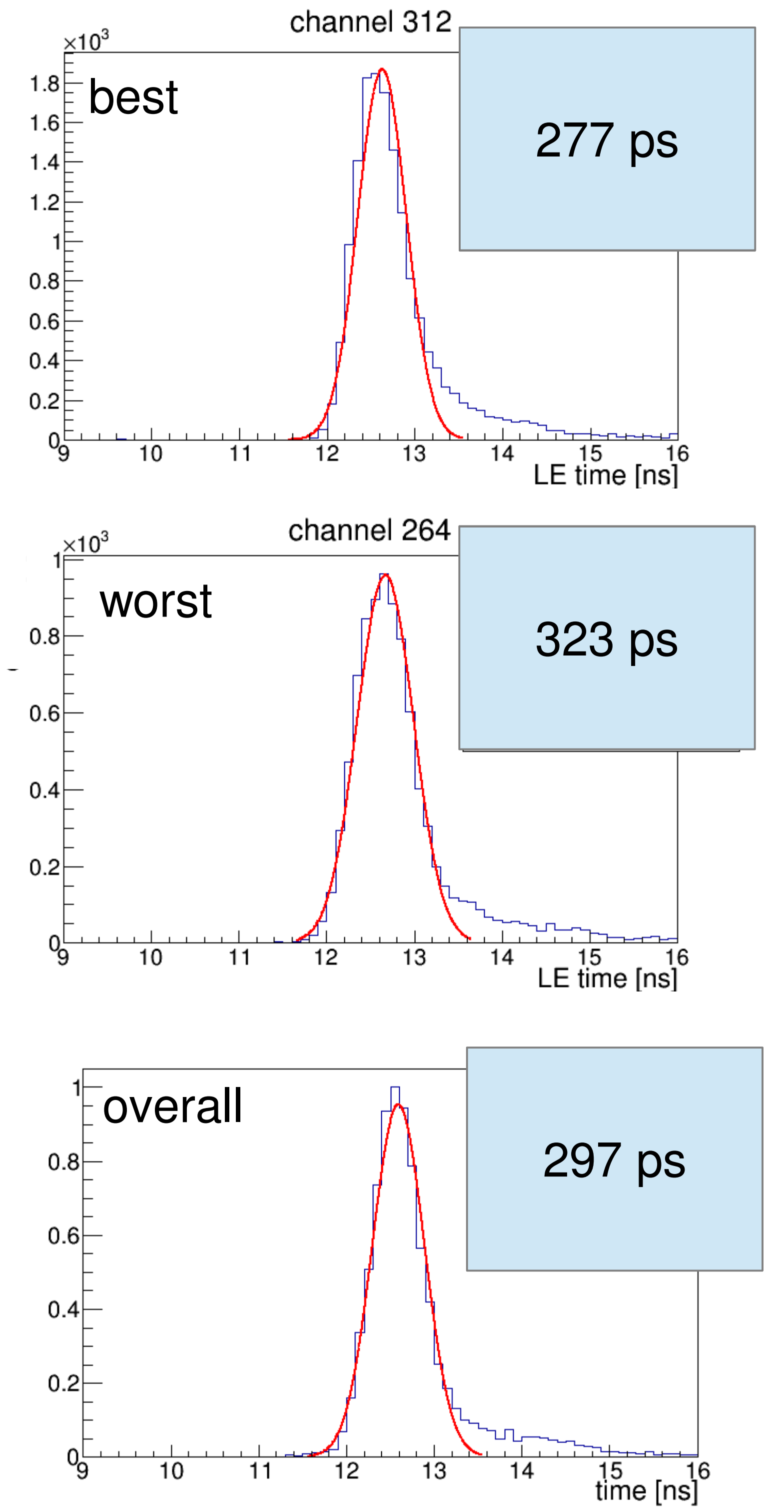




Largest Contribution:

PADIWA Discriminator





Timing resolution determined by

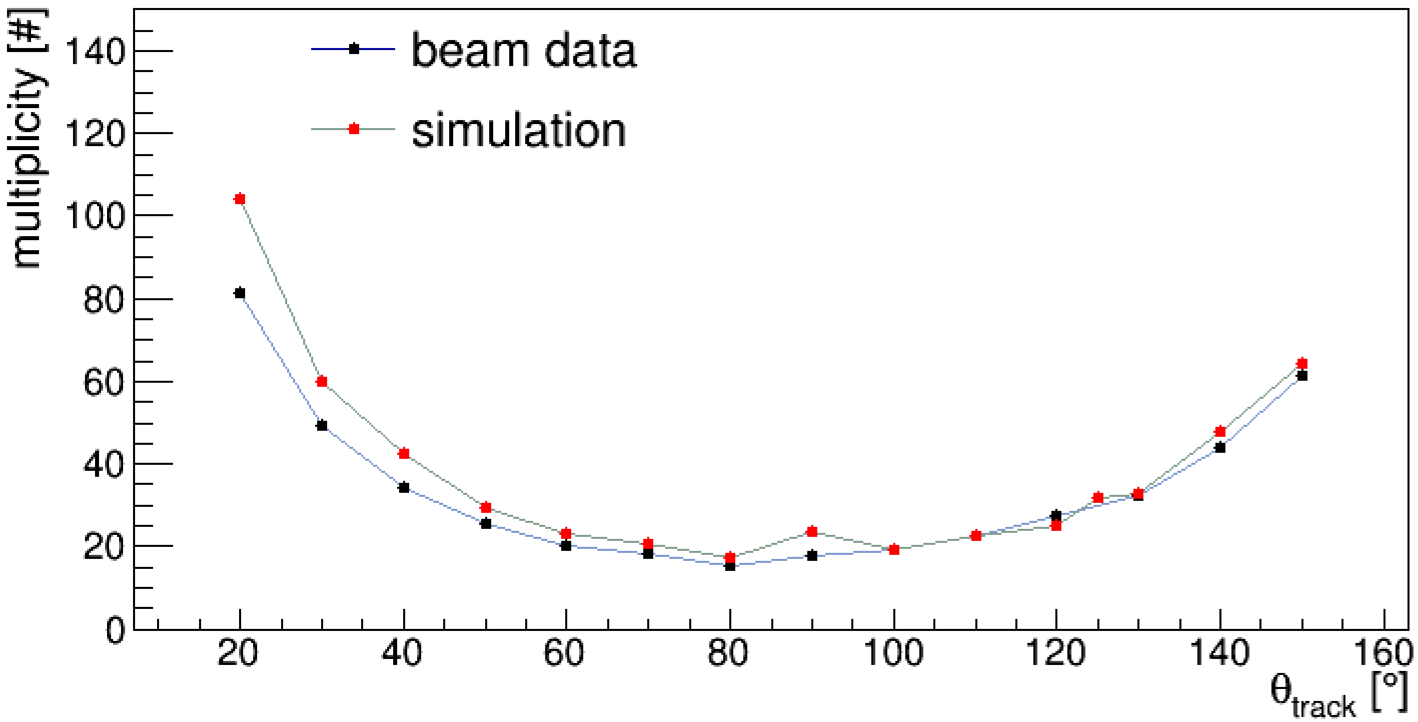
- chrom. Disp.
- PMT
- PADIWA
- TRB

Timing resolution is important for the plate

Number of photons

7 GeV/c
3 component lens

prelim.



Number of photons described by simulation on a 10% level
Details remain to be investigated

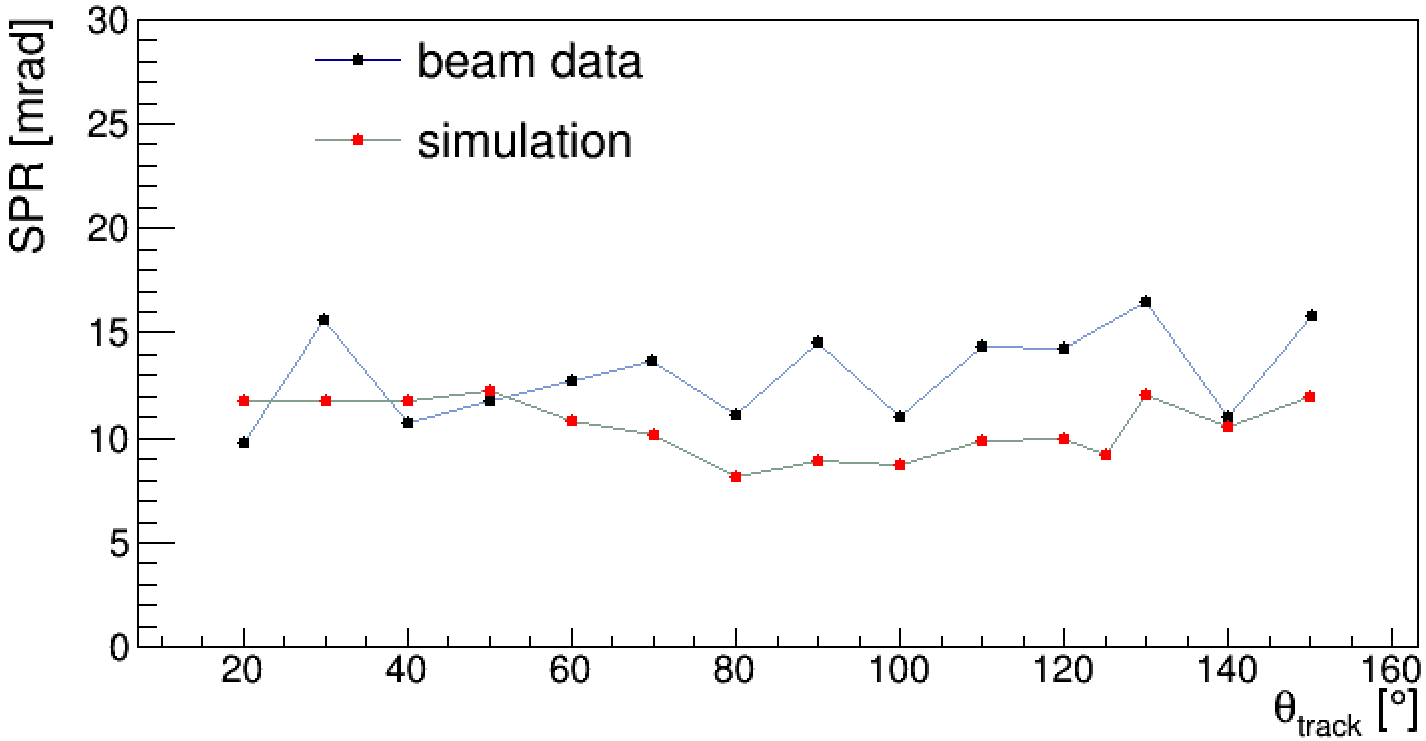
Single photon angular resolution

Geometrical reconstruction

Afternoon, Roman Dzhygadlo

7 GeV/c
3 component lens

prelim.



10 mrad

SPR 30% worse than simulation
Details remain to be investigated
(eg. charge sharing, beam divergence not taken into account)

Afternoon, Lee Allison

@ 3 GeV/c: PID with naked eye possible

(125°, 3 compound lens)

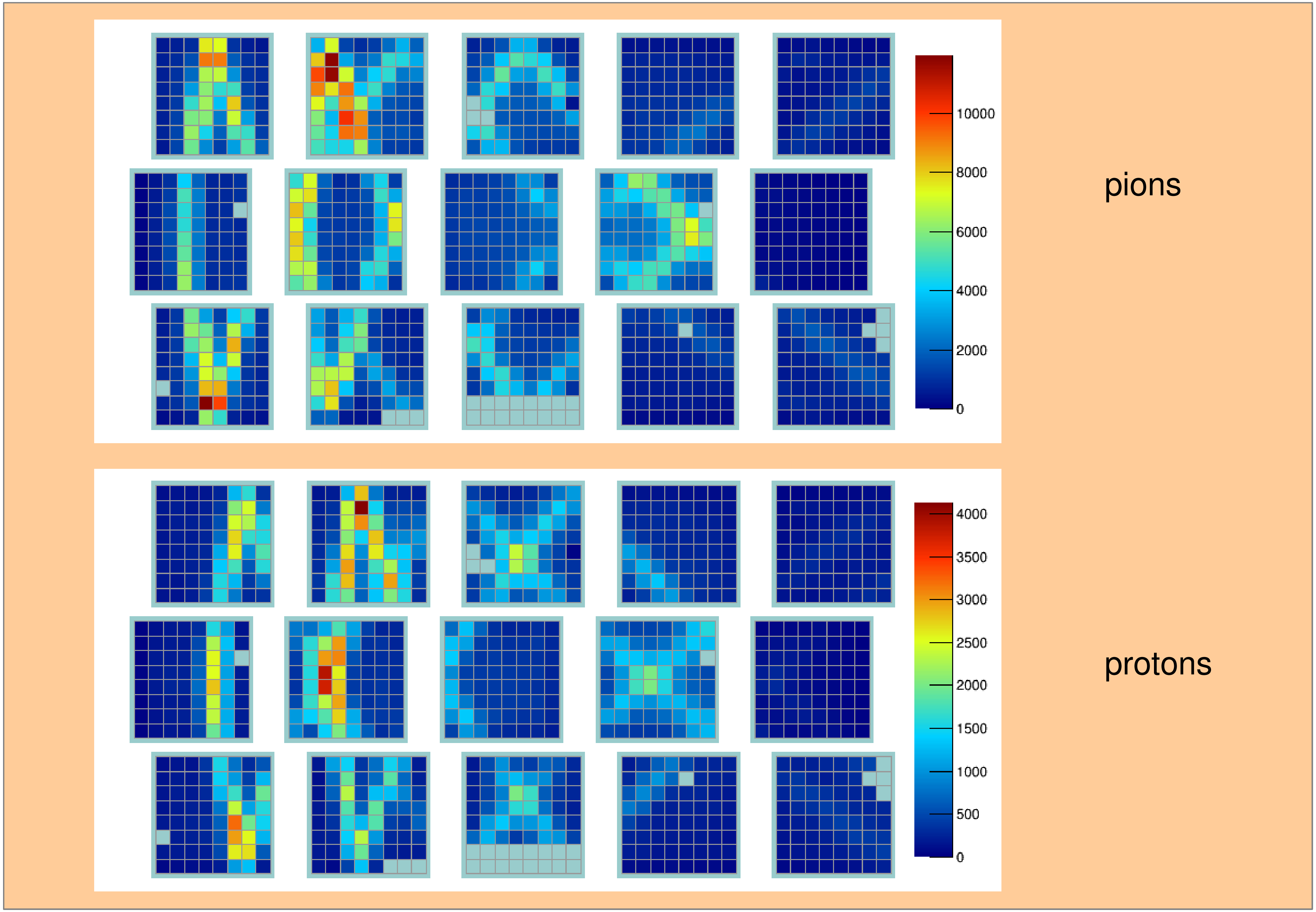
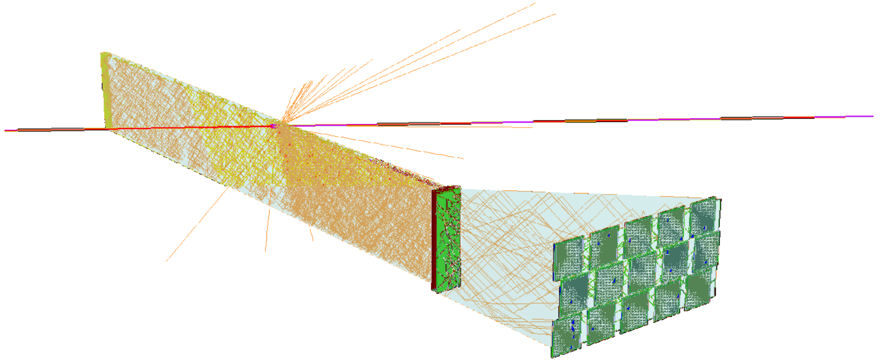
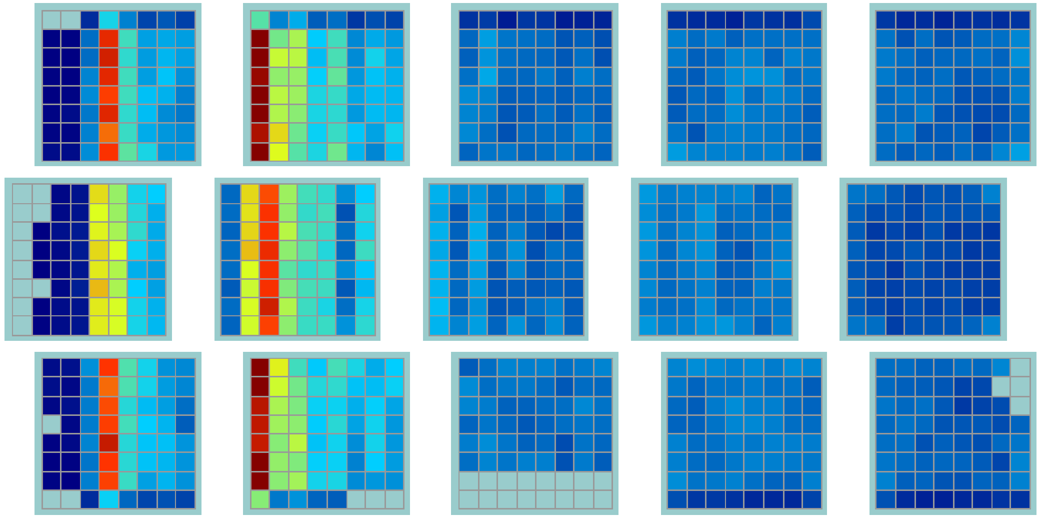


Plate prototype in beam 2015

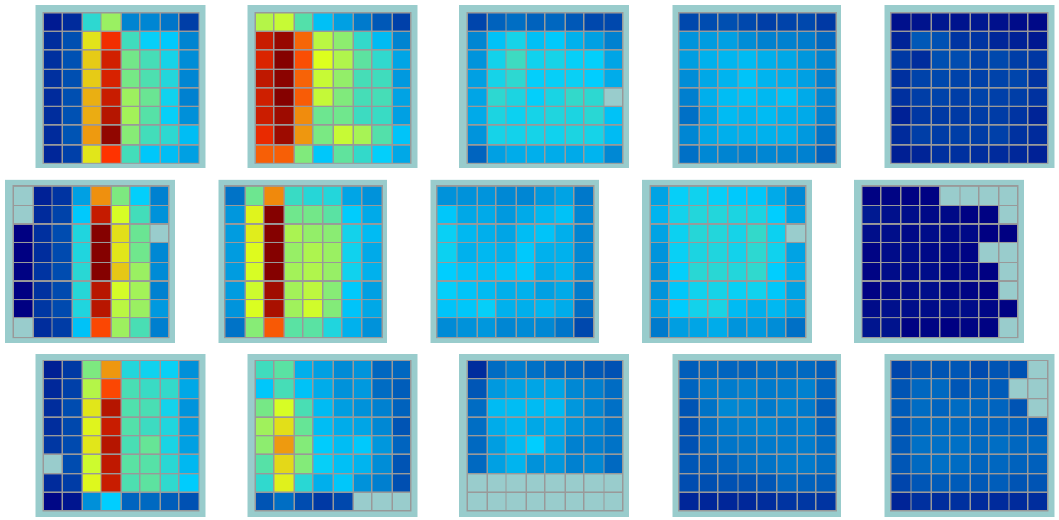
Test of wide plate with and without focusing

7 GeV/c, polar angle 55°, cyl. Lens





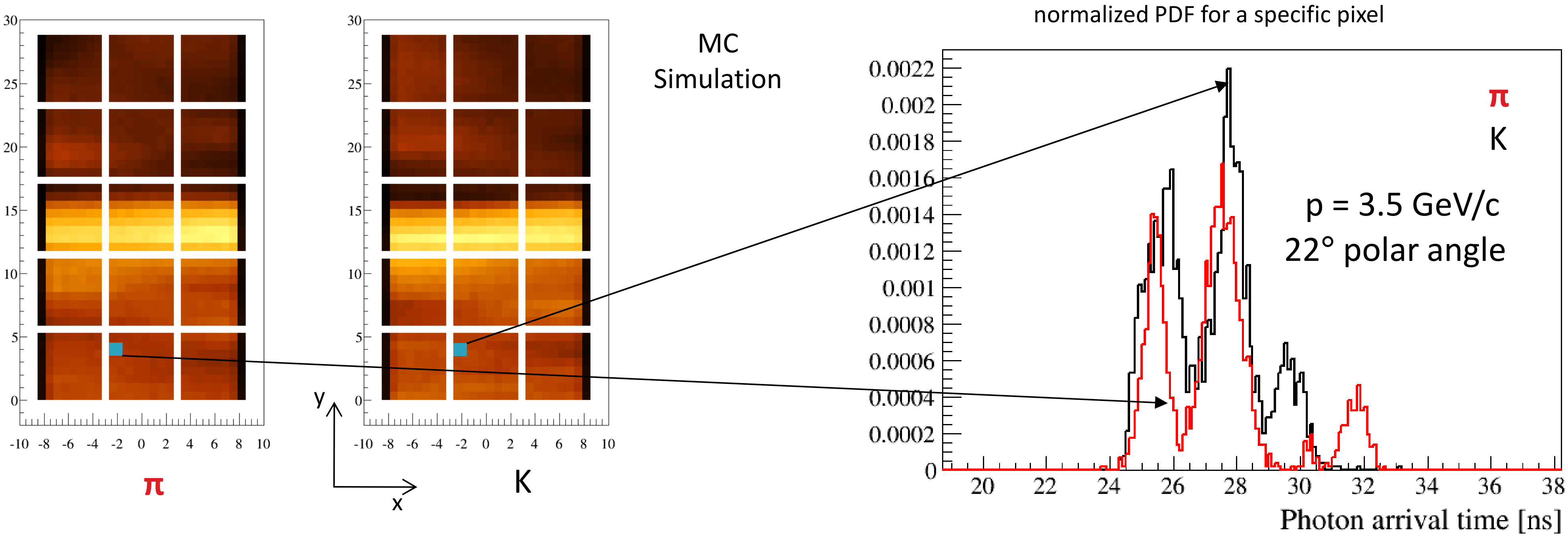
Simulation



Data

Plate: Simulation

At 3.5 GeV/c no difference visible in x-y

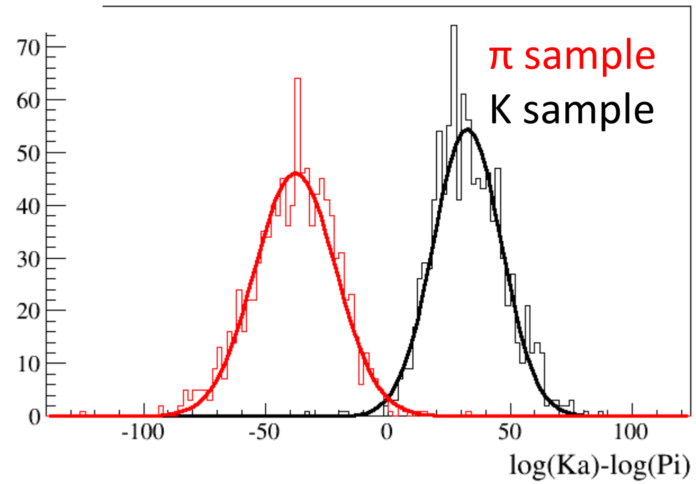


PMT map, with 5 x 3 sensors, 64 pixels each

In **3 dimensions** (x, y, t) hit patterns show **differences** between particle species

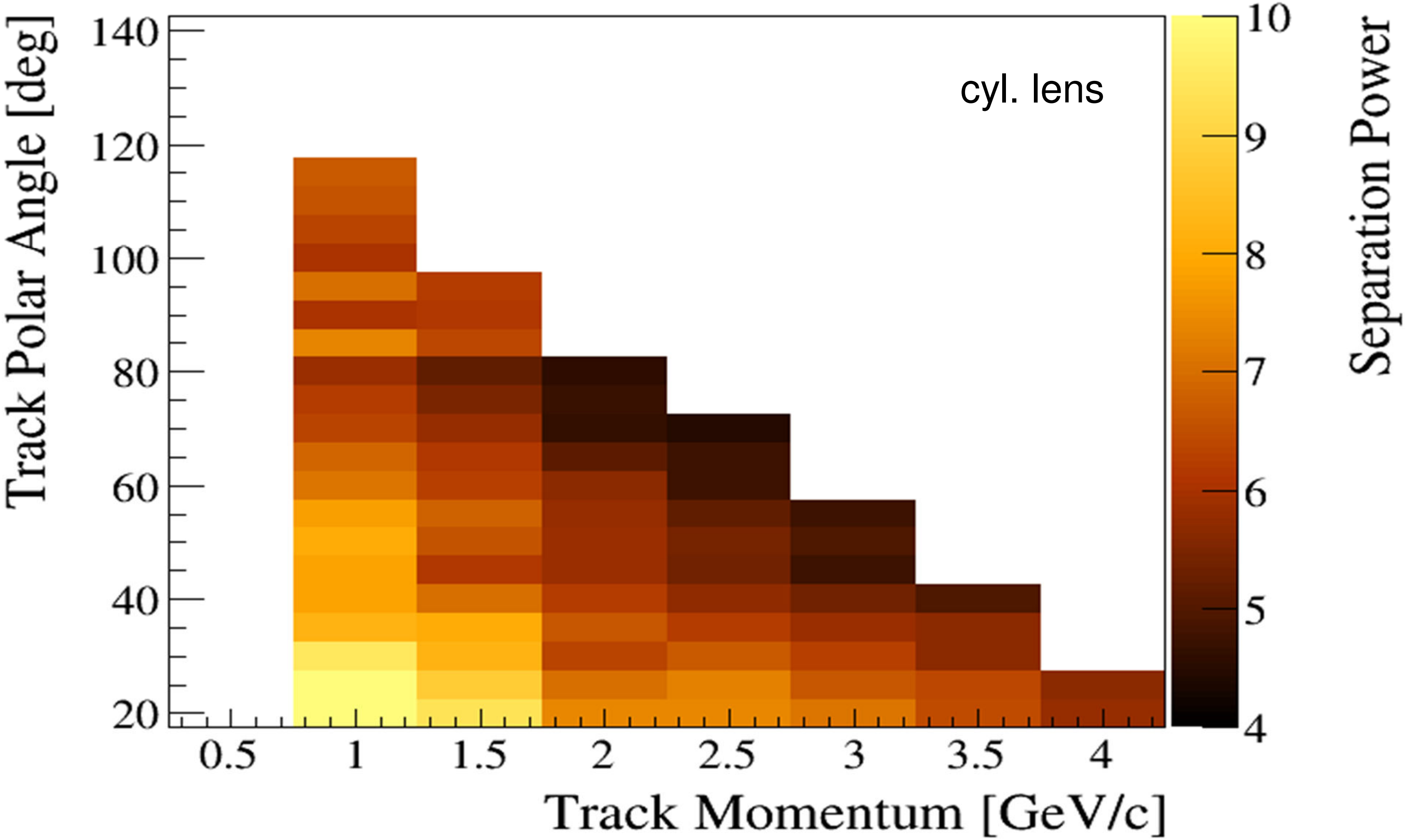
Probability density functions (**pdf**) can be generated with ~100k **Monte Carlo** tracks with same parameters and saved in histograms.

Inspired by Belle II TOP



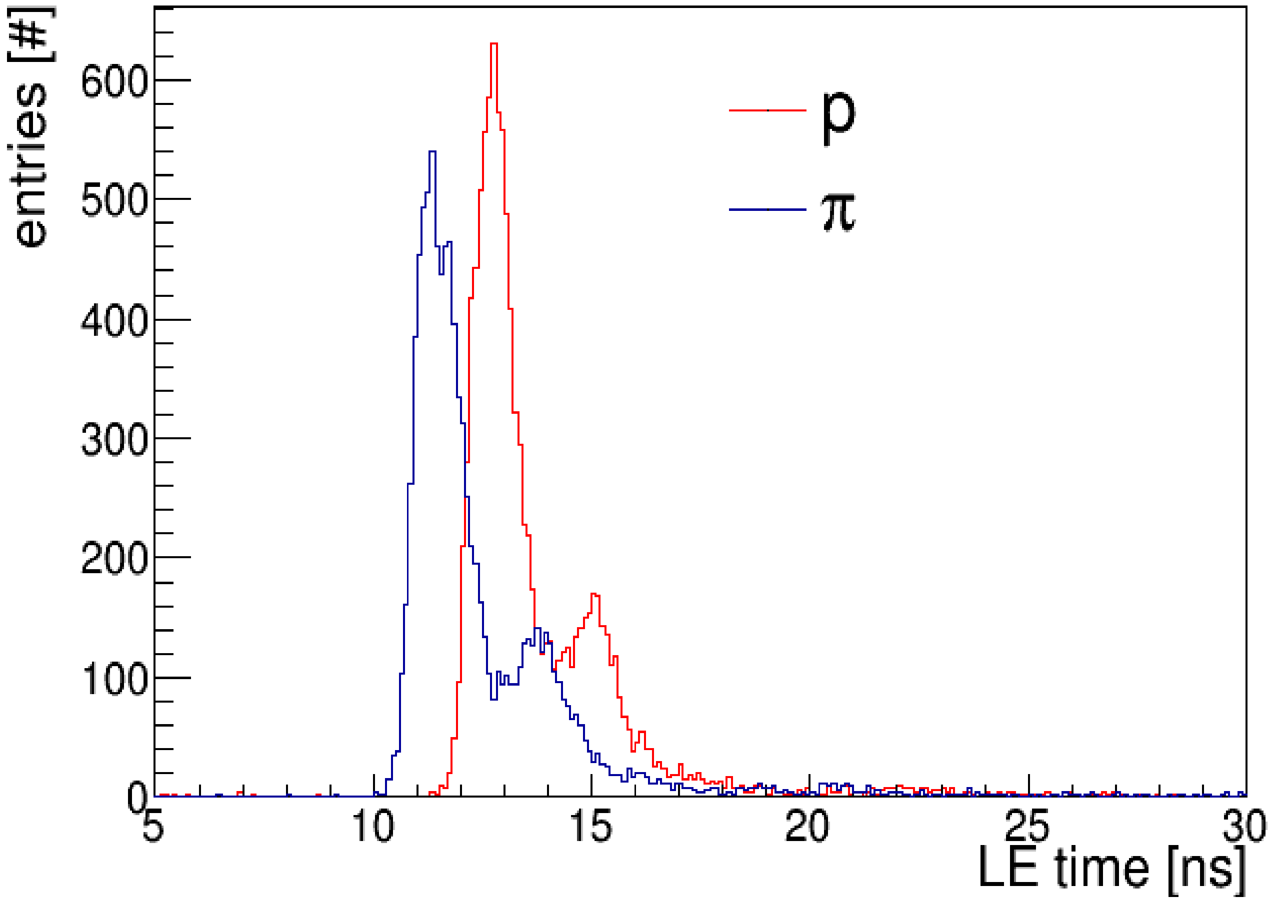
Likelihood ratio test   ln*L*K-ln*L*P

Afternoon, Roman Dzhygadlo



In simulation this method
works over the full
phase space

Not yet proven on data



P = 7 GeV/c (CERN, 2015)
55º polar angle

Time difference clearly visible

Reconstruction remains to be done

Summary

- **Baseline design** of the Barrel DIRC with narrow bars and high-refractive lens index meets **PANDA PID goals**.
- Cost optimization identified two **design alternatives** (wide plate, solid fused silica camera), to be validated with **prototype** tests.
- Prototype tests show promising results
  - Number of observed photons
  - Single photon angular resolution
- Plate still needs reconstruction

Outlook

- Early 2016: Decision about technology (plate vs. bar / prism vs. oil tank).
- Summer 2016: TDR
- Summer 2017 component construction
- 2020 ready for beam

Time resolution

Time spectra (Leading Edge)
show modulation which we ignore
for **walk correction**

Understood:
TOT + small high frequency noise

NIM A791 (2015) 16, Gonella et al.

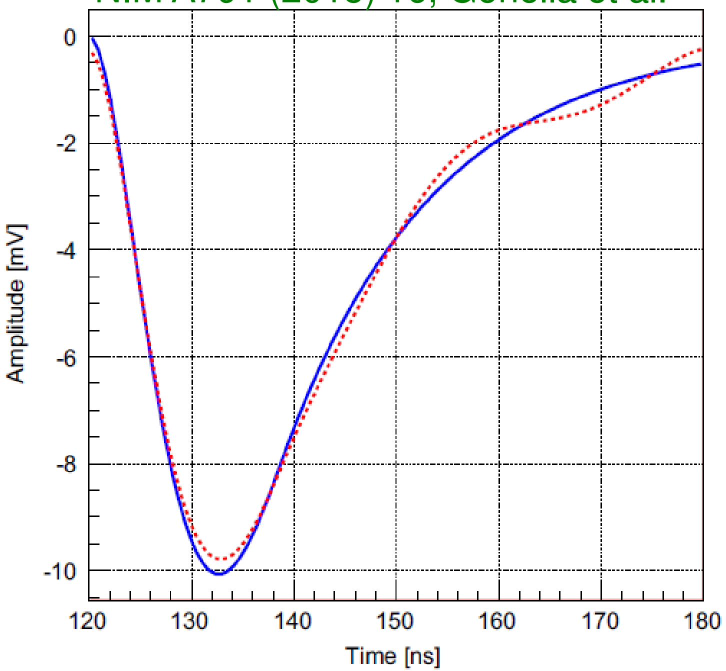


Fig. 5. Simulated shape of the output signal of the system lead-glass block – PMT without (solid curve) and with addition of 300 μV noise at 40 MHz frequency (dashed curve).